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THE

JOURNAL

OF THE

FRANKLIN INSTITUTE,

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DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

GEORGE F. BARKER,

ASSISTED BY THE COMMITTEE ON PUBLICATION.

Vol. XCIX.—Nos. 588–593.

THIRD SERIES.

Vol. LXIX.—JANUARY TO JUNE, 1875.

PHILADELPHIA:
PUBLISHED BY THE FRANKLIN INSTITUTE AT THEIR HALL.
1875

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JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

Vol. LXIX. JANUARY, 1875. No. 1.

EDITORIAL.

ITEMS AND NOVELTIES.

The Belgian Government Prizes.—The following is the text of the official letter from the King of Belgium to the Minister of the Interior, establishing the grand governmental prize. It is published in the official column of the *Moniteur Belge*, of December 15th:

"My Dear Minister: Desiring to contribute, as much as is in my power, to the development of intellectual labor in Belgium, I hereby announce my intention to institute, during the continuance of my reign, an annual prize of 25,000 francs, designed for the encouragement of intelligence in workmanship. This foundation, in my opinion, should possess a double character. It should have for its object, firstly, to stimulate intellectual labor in our own country; and in the second place, it should call the attention of the citizens of other countries to questions of interest to Belgium, and in this way associate Belgium with the progress which the sciences, letters, and arts are making outside her domain.

"In consequence of this opinion, the prize which I hereby institute will be awarded upon the following conditions, and in the following manner:

"During the first three consecutive years it will be awarded to the best work published in Belgium, by a Belgian, upon subjects to be

designated beforehand, the award not to be made until five years after the announcement of the subject. The fourth year, citizens of other countries will be admitted to competition, and the prize will be awarded to the best work published either by a Belgian or by a foreigner, upon a subject of interest to Belgium, also announced in advance. In this way, every four years, a draft will be made upon the progress and the discoveries of other countries for the benefit of Belgium. The fifth, the sixth, and the seventh years, the prize will be again restricted to productions exclusively Belgian; the eighth year, those of other countries will be again admitted, and so on during each period of four years.

"A jury of seven members will be designated by the Minister of the Interior, acting in concert with myself, for the purpose of deciding upon the works presented. The subject matter of the *concours* being changed each year, the jury will also be modified every year.

"The jury, on the years when foreigners compete, will be composed of three Belgian, and of four foreign members of different nationalities. The president will be a Belgian. I do not believe that there will be found, among the savants of any country friendly to us, any who will refuse to assist us, or to decline to take their places with the Belgian jurors in Brussels.

"Not wishing to postpone for five years the execution of my purpose, I desire that, as a temporary arrangement, the first award of the prize shall be made during the September fêtes of the year 1878.

"For the first four years, the prize will be thus awarded: In 1878 (competition exclusively Belgian), for the best work upon our national history; in 1879 (also exclusively Belgian), for the best work on architecture; in 1880 (exclusively Belgian), for the best work upon the development of the commercial relations of Belgium; in 1881 (competition mixed), for the best work upon the methods of improving seaports situated upon low and sandy coasts like our own.

"Next year, the subject for which the prize will be awarded in 1882, will be announced, and so on; each year the subject will be announced for which the prize will be awarded five years thereafter. I beg of you, my dear Minister, to take the necessary steps to carry into immediate execution the plan of which I have now sketched to you the outline, and to receive anew the expression of my affectionate regard."

"LEOPOLD."

Brussels, December 3d, 1874.

Explosives as Sources of Power.—In considering the motive power of the future, it is impossible not to reflect upon the possible utilization for this purpose of explosive agents, such as gunpowder, the picrates, etc. They all may be considered as magazines of immense power, incomparably greater than the power stored up in any of the ordinary combustibles, such as coal or petroleum. In this view of the case, the following extract from a paper by M. Champion, an excellent authority upon the subject, becomes interesting:

"It is estimated that the explosive power of nitro-glycerin is equal to ten times that of gunpowder, and that half a kilogram (1·1 pounds) would lift from the ground and project a weight of 160,000 kilograms. The heat evolved in the reaction is about 1,282,000 calories for each kilogram. This same kilogram of nitro-glycerin, exploding in a closed space having a volume of one liter, develops a theoretical pressure of 243,000 atmospheres, a temperature of 93,400 degrees, and a quantity of heat equal to 19,700,000 calories.

"One liter of nitro-glycerin weighs 1·6 kilograms. In exploding in a space completely filled with it, as happens in a blast-hole in mining operations, or when operating under water, this substance develops a pressure of 470,000 atmospheres; a pressure eight to ten times that produced by the same volume of gunpowder.

"The heat thus developed being 38,000,000 calories, the mechanical labor produced, which is the equivalent of this, rises to the enormous number of more than sixteen thousand million kilogram-meters, a value five times that of the maximum value of gunpowder."

"A kilogram of coal contains about 8000 calories," says the *Revue Industrielle*, "each calory being equivalent, theoretically, to 120 kilogram-meters. Hence, the maximum mechanical work of 1·6 kilograms of coal would be 5,476,000 kilogram-meters; a quantity 3000 times less than is produced with the same weight of nitro-glycerin.

"Is not the imagination of the most enthusiastic inventor" it continues, "staggered in presence of these enormous numbers? What an answer, too, do these figures furnish to the pessimists who see in the exhaustion of our coal mines the extinction of the industries of the future! *In a single liter of nitro-glycerin there is stored up the enormous labor of 5500 horse-powers acting continuously for ten hours!*"

Japanese Paper.—In the Japan department of the Vienna Exhibition, a series of objects made from paper were exhibited which excited great interest. Among other articles, there were to be seen in this collection, handkerchiefs, towels, umbrellas, cloaks and other articles of dress, lanterns, etc.; and all made of paper, of a texture exceedingly firm. The manufacture of such paper is extremely complicated, and is almost unknown in Europe and America. The following facts in relation to it are taken from a Report recently made upon this subject to the Society of German Orientalists, by M. Zappe.

For the manufacture of their paper, the Japanese have used for centuries the bark of the *Broutonessia papyrifera*, which grows throughout almost the entire extent of the empire. The culture of the plant is very simple: old roots, cut into lengths of about four inches, are thrust into the ground so that about an inch projects above the surface. The first year these roots give a growth of shoots about a foot long, and the second year a growth of two to three feet. At the end of the third year the plant has a total height of nearly fourteen feet. The tenth month of each year these shoots are cut off on a level with the top of the root. Each shoot consequently yields five branches; so that at the end of five years there is formed a large, bushy tree, the branches of which may be used for the manufacture of paper.

The branches are cut for this purpose in winter. They are divided into pieces of twenty-eight inches in length, and these are heated in water until the bark is readily removed by the hand. This bark is then seasoned by exposure to the air, an operation which requires from two to three days at the ordinary temperature, and twenty-four hours only during high winds. After an immersion of at least twenty-four hours in running water, the bark is submitted to the action of a sharp cutting edge placed above a matting of straw; the object being to separate the two sorts of fibers of which it is composed; the exterior fibers, dark in color, "*saru kawa*," being used in the preparation of a paper of inferior quality, such as the *chiri gami*, or the *kizo suki*.

The finer varieties of paper are made with the interior fibers, called *sosori*. These are rolled together in balls of about thirty pounds weight, which are washed in running water, are then placed in flat tanks of water, and are withdrawn after a certain time and the water pressed out. They are then heated in a lye made from the ashes of

buckwheat bran, taking care to agitate them constantly with stirrers, until the liquid is brought to active ebullition. A new washing in running water deprives them finally of all impurities. They are withdrawn and subjected for twenty minutes to a beating upon a block of oak or cherry; after which they are collected into bales and placed in heaps, forming the material for the pulp.

During the fabrication of the paper, there is added to the liquid mass a little *tororo*, extracted from the root of the *hibiocus manihot*. In summer, rice-water is also added, in order to prevent the ravages of worms. The pulp thus obtained is subsequently made into paper by a process analogous to that employed in Europe for making paper from rags.

The variety called leather-paper is made by the superposition of several layers of the paper called *toza-senka*. These are first soaked in the oil of the yenoki (Cellis wildenowiana), then, after having subjected them to strong pressure, they are covered with a layer of lacquer.

Clothing is made with a paper called *shifu*. The sheets of this paper are cut into strips, more or less wide, according to the fineness of the material to be made. These are then twisted into threads by the fingers previously moistened with milk of lime. These threads are woven into cloth, either alone, or mixed with silk. The materials made of them can be washed, and have great strength.

Crape-paper is made with very firm sheets, which are first moistened with water, and over which is rolled, first lengthwise and then crosswise, a wooden roller, on which is engraved the design.

Besides the *Broutonessia papyrifera*, the Japanese employ also the *Edgeworthia papyrifera*, in the manufacture of paper. The mode of manufacture is identical with that which has just been described.

Very Resistant Glass, almost Malleable.—A manufacturer of Pont-d'Ain, M. de la Batie, has discovered a means of rendering glass almost malleable, and is about to erect a factory for the production of articles of this new glass. From his patents it appears that his process consists in annealing the glass while yet in a pasty state, at the time of its fusion and in the furnaces where it is made. This annealing should be effected in a liquid *ad hoc* and under special conditions. This operation, while it does not render the glass absolutely malleable, increases its resisting power about forty times. We have

seen, says the *Revue Industrielle*, an ordinary pane of window glass thus annealed, upon which was allowed to fall from a hight of six feet a five franc piece, without causing the least damage. The importance of this discovery in all branches of glass manufacture cannot fail to be very great. The new glass works of M. de la Batie will be established at Pont-d'Ain. A company has been formed with a capital of 250, 000 francs for the purpose of putting the invention into practical operation.

Bibliographical Notices.

TABLES FOR THE DETERMINATION OF MINERALS *by those Physical Properties ascertainable by the aid of such simple Instruments as every Student in the Field should have with him.* Translated from the German of Weisbach. Enlarged and furnished with a set of Mineral Formulas, a column of Specific Gravities, and one of the characteristic Blowpipe Reactions. By PERSIFOR FRAZER, JR., A. M., &c. 12mo., pp. 117. Philadelphia, 1875. J. B. Lippincott & Co.

The German student of Mineralogy is fortunate in having at disposition quite an array of convenient tables to aid him in his determinations. Of these Handbooks, or *Tafeln zûr Bestimmûng der Mineralien,* the works of Weisbach, Blum, v. Kobell, and Fuchs are perhaps the best known. Most of them, however, are only of value in the class room or the laboratory, or premise considerable practical acquaintance with crystallography. The work of Blum, for instance, is purely crystallographic; that of v. Kobell, though making a primary division into minerals with and without metallic lustre, identifies them solely by their chemical properties, while that of Fuchs combines the features of both. None of these works are well adapted to the wants of the student, prospector, or mineral collector when in the field and deprived of the convenient accessories of the laboratory. The wants of this large class have been recognized and admirably met in the Tables of Prof. Weisbach, which the translation of Prof. Frazer has made accessible to those who are not familiar with the language of the original.

In these tables the minerals are divided into three classes, which are readily determined by simple inspection, viz.: those of metallic lustre; those of non-metallic lustre which give a colored powder; and those of non-metallic lustre and colorless streak. The subdivisions which lead to the specific identification of the species are

founded, first on the test of hardness, which is then supplemented by the additional aids of the other physical properties, color, tenacity, crystallization, and cleavage.

Armed with the few simple paraphernalia, which the student or collector in the field is always supposed to carry—hammer, file, knife, streak-tablet, and magnifier—he is prepared, with the aid of this pocket bock, to identify most of the minerals he may meet. We can cordially recommend the tables as highly useful and conveniently arranged, and trust, at the same time, that one criticism that we have heard passed upon them may find no grounds in a second edition, by the interpolation of a number of distinctively American species that are wanting in this one. W.

Franklin Institute.

SPECIAL MEETING.

Hall of the Institute, Dec. 7th, 1874.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

The President stated the object of the meeting, and ordered the reading of the call on account of which he had authorized it.

The Secretary then read the following communication:

Hall of the Franklin Institute, Dec. 2, 1874.

Coleman Sellers, Esq., President Franklin Institute.—Dear Sir — The undersigned members request that you call a special meeting of the Institute on Monday next, 7th inst., to prepare for the Board of Managers at their meeting on the 9th inst., plans for the *immediate* augmentation of the Library and alteration of the Building.

(Signed by 21 members.)

The President thereupon pronounced the meeting ready to proceed with its special business.

The Actuary presented the following resolutions from the Library Committee, which had been passed at its meeting Dec. 7th, 1874:

Resolved, That the following resolutions be recommended to the Institute for adoption:

1st. That the Board of Managers be requested to make an appropriation to the Library Committee, which will enable it to make the library more nearly complete for the purposes of the Institute.

2d. That the Library Committee be authorized to sell such books as have no reference to the purposes of the Institute.

Mr. Wm. P. Tatham moved the adoption of the resolutions.

Mr. Joseph Willcox objected to the first resolution, that it was too indefinite, and that a sum of money should be appropriated; or at least a sum named as a limit.

Mr. B. H. Moore suggested that the sum to be appropriated might safely be left to the discretion of the Board of Managers.

Mr. Willcox moved to amend the first resolution by inserting that "the sum to be expended shall not exceed $10,000."

Mr. Tatham, in reply to an inquiry from the meeting, described the kind of books in the library proposed to be sold by the second resolution.

Mr. J. E. Mitchell doubted the expediency of spending so much money as $10,000 in the present location of the Institute.

Mr. Moore urged that the immediate expenditure of a respectable sum of money for the augmentation of the Library, was a matter of prime importance, but added that the Board of Managers was the proper authority to decide upon the sum to be thus expended.

Dr. J. S. Cohen wished to know what sum the committee had in view in their resolutions.

Mr. J. W. Nystrom, from the committee, named $2000 to $3000.

Mr. Cheney offered as a second amendment to the first resolution, that the sum to be appropriated be left to the judgment of the Board.

Mr. S. Lloyd Wiegand asked for information as to whether the general meeting was competent to order the appropriation of money, or whether its authority was not limited to the passage of a suggestion or recommendation to the Board. The President, in reply, read from the By-Laws the section referring to the functions of the Board, and explained that all authority in matters of finance was solely vested in the Board, and that it alone possessed authority to order the expenditure of moneys of the Institute.

The second amendment, which leaves the amount of money to be expended, to the discretion of the Board of Managers, was thereupon put to the meeting and was carried. As the first amendment was

neutralized by the passage of the second, it was withdrawn. The question upon the first resolution as amended was then put to vote, and carried.

Upon the second resolution, Mr. Hector Orr inquired whether the Board of Managers had the authority to sell any property of the Institute, without previous consent obtained from a meeting of the stockholders. The President read for the information of the meeting from the By-Laws, the powers of the stockholders.

Mr. Chas. S. Close remarked that if the Library Committee should report that a lot of useless material was taking up valuable space imperatively needed for useful purposes, no one would raise objection as to its sale, or inquire upon what authority it was disposed of.

Mr. Tatham said that the object of the Committeë in presenting the second resolution was to get more space in the Library room.

Mr. Cheney amended the resolution by the clause, that "the proceeds of such sale be devoted to the improvement of the Library." The amendment was accepted on behalf of the committee by Mr. Tatham. The resolution as amended was offered to the meeting and carried.

The two resolutions as amended and adopted, read as follows:

Resolved, That the Board of Managers be requested to make an appropriation to the Library Committee which will enable it to make the Library more nearly complete for the purposes of the Institute, the sum to be thus appropriated being left to the discretion of the Board.

Resolved, That the Library Committee be authorized to sell such books as have no reference to the purposes of the Institute, the proceeds of such sale to be appropriated to the improvement of the Library."

Mr. Thomas Shaw referred to the privileges conferred upon the stockholders as being extraordinary, and inquired whether any alteration of the building was possible without their consent having been first obtained. The President decided that the consent of the stockholders was not needed.

Dr. Cohen referred to the necessity of having a printed catalogue for the library, and moved that the importance of this matter be urged upon the Library Committee. Carried.

Mr. Robert Grimshaw next presented certain views concerning the future policy of the Institute, involving a considerable expansion of

its present operations, and in conclusion offered the following resolutions:

Resolved, That it is the sense of this meeting that the Board of Managers be urged to take such action at their next meeting as will result in the most speedy alteration of the present building to adapt it to the wants of the Institute, and to introduce steam heating and ventilating arrangements in all parts under the supervision of a joint committee composed equally from the Board and the members at large.

Mr. Nystrom suggested that the committee that had been authorized at the last meeting was the proper one to which to refer the resolution just offered.

Mr. Mitchell protested against the tenor of the resolution. He urged that it should be the aim of the Franklin Institute to emulate the usefulness of the many Polytechnic Institutes of Europe; instancing those of London, Paris, Berlin, and especially that of Vienna, as excellent models. He added that it was impossible to place the present building upon such an extensive basis as was demanded by the spirit of the times. He further urged the appropriation of the profits of the late exhibition, and of the money that might be derived from the sale of the present lot and building occupied by the Institute, to the purchase of another site and the erection of another building.

Mr. Wiegand next occupied the floor in defence of the resolution. He claimed that the Institute was not making by any means the best use of the place and room it now possessed; and explained at length, with the aid of projections on the screen, a plan suggested by certain members of the Institute to remodel the present building. The plan in question involved the enlargement of the lecture room to nearly twice its present seating capacity, besides increasing its conveniences for illustrative purposes and lectures, an equivalent enlargement of the present library room and drawing school, the establishment of efficient laboratories, and the steam heating of the whole building. These alterations, he asserted, could be effected at a cost not exceeding \$5000.

Mr. Mitchell thought the plan described was altogether inadequate to the wants of the Institute, and moved that the resolution be referred to the committee to be appointed by the President at the next regular meeting.

Messrs. Shaw and Gray opposed such reference, as the result would be simply to bury it, and the purpose of the mover of the resolution was to obtain the sense of the present meeting on the subject.

The question was still further debated by Messrs. Gray, LeVan, Leffmann, Wise, Orr, Bennet, Close, and Branson.

The question upon Mr. Mitchell's amendment to refer to a committee was lost, and the resolution was thereupon carried.

The meeting was then, on motion, adjourned.

WILLIAM H. WAHL, *Secretary.*

HALL OF THE INSTITUTE, December 16th, 1874.

The meeting was called to order at the usual time, with the President, Mr. Coleman Sellers, in the chair.

The minutes of the last meeting were read and adopted, as also those of the special meeting held Monday, Dec. 7th.

The Actuary then submitted the minutes of the Board of Managers, and of the several standing committees. He likewise reported the following extracts from the minutes of the Board, viz.:

"*Resolved*, That a committee be appointed by the Board to prepare and submit plans for the improvement of the present Institute building." Carried.

The President then appointed the following gentlemen, six from the Board and six from the members at large, to serve upon that committee, viz.:

From Board.—Chas. S. Close, J. Vaughan Merrick, Joseph M. Wilson, Robert E. Rogers, E. J. Houston, J. E. Mitchell.

From Institute.—Robert Grimshaw, S. Lloyd Wiegand, J. B. Knight, J. Solis Cohen, Wm. B. Bement, John McClure.

The Actuary, from the minutes of the Board, likewise reported that at their last meeting the following donations to the library had been received:

Annales des Ponts et Chaussées, for July and August, 1874. Paris. From the Editor.

U. S. Coast Survey Report, 1874. Appendix: Tidal Researches, by Wm. Ferrel, A. M. Tidal Discussion of Tides in Boston Harbor,

by Wm. Ferrel. Washington, 1874. From C. P. Patterson, Superintendent.

Report of the Department of Agriculture for 1873. Washington, 1874. From the Commissioner.

Mittheilungen der K. K. Geographischen Gesellschaft in Wien, for 1873. Vienna, 1874. From the Society.

Zeitschrift des Architekten und Ingenieur Vereins zu Hannover. Vol. XX, Part 2. From the Society.

Documents relatif au Congrés International des Sciences Geographiques, qui se réunira á Paris en 1875. Paris, 1875. From the Commissioner.

Circulars of Information of the Bureau of Education. No. 2, 1874. Washington. From the Bureau of Education.

Tilghman's Sand Blast. From Gorham Blake, General Agent for the U. S.

Annual Report upon the Improvement of Rivers and Harbors in New Jersey, Pennsylvania, and Delaware, in charge of J. D. Kurtz, Lieut.-Colonel of Engineers, etc., U. S. A. Washington, 1874. From the author.

Minutes of Proceedings of the Institution of Civil Engineers, with abstracts of the Discussions. Vols. 37-38. London. From the Society.

Report of the Chief Signal Officer, War Dept. 1872-73. From the signal officer at Philadelphia.

Report of the Commissioner of Fish and Fisheries, Part 2, for 1872-73. Washington. From the Commissioner.

The report of the Secretary on novelties in science and the mechanic arts next followed; upon which the President gave an account of a recent discovery of mica in considerable quantities and of good quality on the coast of Labrador.

Nominations for officers of the Institute were then declared in order, and the President announced that, in accordance with the By-Laws, there were to be chosen at the stated meeting next following, a President, Secretary, Treasurer, and Auditor, to serve for one year, a Vice-President and eight Managers to serve for three years, and, in consequence of the resignation of Mr. F. B. Miles from the Board, before the expiration of his term of office, one Manager to serve for two years.

The following members were then put in nomination:

For President, Coleman Sellers (declined), Bloomfield H. Moore, Dr. Robert E. Rogers.

For Vice-President, J. E. Mitchell, Coleman Sellers, Charles S. Close, Wm. P. Tatham.

For Secretary, William H. Wahl (declined), J. B. Knight, Robert Grimshaw.

For Treasurer, Fred'k Fraley.

For Managers for three years, Theo. D. Rand, Thos. Shaw (declined), Thos. J. Lovegrove, Sterling Bonsall, Washington Jones, G. Morgan Eldridge, Jas. M. Wilson, Coleman Sellers, William H. Wahl, Pliny E. Chase, Th. Norris, Jr. (declined), Chas. S. Close, Wm. P. Tatham, Stephen P. M. Tasker (declined), Geo. F. Barker, Cyrus Chambers, Jr., Chas. H. Cramp, J. Sellers Bancroft, John H. Cooper (declined), Chas. H. Heller, Chas. M. Cresson, Wm. B. Bement, Sam. S. Hart (declined), Isaac Norris, Jr.

For Manager for two years, Samuel Hart, Alex. Purves, Geo. V. Cresson, and

For Auditor, James H. Cresson.

The President then announced the appointment of the following members to serve as Judges of the Election. namely:

William A. Rolin, Geo. Gordon, M. W. Haines, John Hoskin, William Biddle, Samuel Sartain, and William Taggart.

The Secretary then read by request a paper presented by Mr. Thomas Shaw, alleging a number of grievances suffered by various exhibitors who participated in the late exhibition, and charging upon the Board of Managers certain irregularities—notably in their not complying with their printed rules and regulations, and in overstepping their authorities. On the conclusion of the reading Mr. Shaw offered the following preamble and resolution, viz.:

WHEREAS, The action of the Board of Managers in making awards of premiums on articles competing at late exhibition has caused a great deal of dissatisfaction on the part of exhibitors, who complain that the Board has not complied with the rules and regulations under which they invited competition; therefore,

Resolved, That a Committee of Appeal, consisting of seven members be nominated by this meeting from among those not managers, which committee shall have power to examine any case which may be

brought before them on appeal and decide whether the award of premium as made by the Board, is in accordance with the rules and regulations adopted and published by said Board, and if they may find said rules have not been complied with, then to modify said award in accordance with said rules and the requirements of justice.

The resolution was seconded by Mr. Gray.

Mr. J. B. Burleigh moved to amend by referring the subject to the Committee on Science and the Arts.

The amendment was discussed pro and con by Messrs. Burleigh, Shaw, and others.

Mr. Henry Cartwright stated that the mover of the resolution was probably not correctly informed as to the official action of the Board upon the awards, and that any misunderstanding could be obviated if the President would state what had been done concerning the adjustment of disputed cases.

The President then stated that he, as well as other officers of the Institute, had been the recipient of a number of complaining letters, and that these had invariably been referred to the Judges; that the Judges of many of the classes had met and reviewed their work in the light of the objections raised, and that they had in a number of instances modified their reports; that, furthermore, these modified reports would be brought up before the Board again on the Monday following. The President then read the form of circular that had been addressed to the Judges for this purpose.

Mr. Sterling Bonsall and Mr. Gray then successively occupied the floor, claiming that the Managers had overstepped their authority in presuming to revise and amend the reports of the Judges; claiming from the statements of the printed rules and regulations, that the choice of the awards of merit was vested in the Judges, and that their decision should be final.

Messrs. Lovegrove and Burleigh then occupied the floor in favor of the amendment to refer to the Committee on Science and the Arts.

Mr. Chas. S. Close remarked that any action upon the resolution or the amendment at this time would be premature, in view of the fact that as yet the report of the Board of Managers had not been officially made public. He therefore moved the postponement of action upon the same until the next monthly meeting.

In connection with the same subject, Mr. Gravenstine called atten-

tion to a communication which he had addressed to the Institute, and was now in possession of the Secretary.

The President decided that the whole subject had been postponed by the resolution just passed.

The President then announced the following committee to consider the subject of the selection of a new site and the erection of a new building for the Institute, which committee had been ordered at the stated meeting previous to this, viz.: Messrs. J. W. Nystrom, chairman; William Sellers, J. Vaughan Merrick, Enoch Lewis, and Henry G. Morris.

The meeting thereupon adjourned.

William H. Wahl, *Secretary.*

SPECIAL MEETING.

Hall of the Institute, December 23d, 1874.

The meeting was called to order at the usual hour, with Vice-President, Dr. Robt. E. Rogers, in the chair.

The Secretary read the following call, in obedience to which the President had authorized the meeting, viz:

Hall of the Franklin Institute, Dec. 18*th*, 1874.

Coleman Sellers, Ex-Pres't.,—Dear Sir:—The undersigned members of the Franklin Institute, respectfully request that a Special Meeting be called for Wednesday Evening, 23d inst., to consider some proposed changes in the By-Laws, to be discussed at the next stated meeting.

(Signed by twelve members and authorized by the President.)

The President *pro tem.*, declared the meeting ready to transact its business.

Mr. Gray then called for the reading of the minutes of the last meeting of the Board of Managers.

The President *pro tem.* decided that the call for the minutes of the Board is only in order at the stated meetings of the Institute.

Mr. Wiegand then read from the By-Laws, Section XV, that the Board shall keep regular minutes of their proceedings, which shall be open at all times to the inspection of members.

Mr. Close remarked that the minutes were at all times open for inspection, but that the present meeting was only interested in the objects specified in the call.

Several members then followed with an inquiry as to the object of the meeting.

Mr. Robert Grimshaw in reply offered the following resolution, which was duly seconded by Mr. George Gordon, viz.:

Resolved, "That a committee of two from the Board of Managers, and five from the members at large be appointed, and instructed to report an amendment to the By-Laws, clearly defining the powers of the Board of Managers."

The reading of the By-Laws on the subject was called for.

Messrs. Close, Grimshaw, Tatham, Purves, and Gray debated the question as to the legality of offering amendments to the By-Laws at a special meeting.

Mr. Wiegand remarked his position as a signer of the call, and defined it to be a meeting to propose and discuss alterations and not to offer or effect them. Amongst other needed modifications, he mentioned as most important, a clear definition of the limits of the Board, and the reorganization of the Committee on Science and the Arts, by undoing the establishment of sections.

Mr. Robert Briggs followed by reading from the By-Laws the section defining the powers of the Board, and presented his views thereon. He wished to inquire what grounds there were for desiring a disturbance of the existing relations.

Mr. Grimshaw, in reply, specified a number of cases in which, in his opinion, the Board had transcended the powers vested in it by the By-Laws, and stated that the object of his resolution was to define clearly, by negative limitations, the powers of that body; but added that since there seemed to be some doubt as to whether he was strictly in order, he would withdraw the resolution.

Some further discussion followed without definite action, upon which the meeting was adjourned.

WILLIAM H. WAHL, *Secretary.*

Civil and Mechanical Engineering.

REMARKS ON THE EXPERIMENTS MADE WITH A SMALL NON-CONDENSING STEAM-ENGINE BY B. DONKIN & CO., LONDON, SHOWING THE RELATIVE ECONOMIC EFFICIENCY OF STEAM-JACKETING, AND OF USING STEAM WITH DIFFERENT MEASURES OF EXPANSION.

By Chief Engineer B. F. Isherwood, U. S. Navy.

The issue of *Engineering* dated October 16th, 1874, contains an article headed "Steam Jackets," in which are given the particulars of the experiments made at the factory of B. Donkin & Co., London, on a small non-condensing beam engine, with a view to ascertain the economy derived from the addition of a steam-jacket to the cylinder. The data appear to me sufficient for the determination of several important facts besides the economy of the steam-jacket; and, in the belief that conclusions wider, different, and more numerous than those drawn by the writer of the article are properly deducible from the observed quantities, I have made the necessary calculations from them in my own way, as given in the accompanying Table, and have inferred from them what seems to me the correct and complete results. Before proceeding to a discussion of these results, I will quote from the article referred to the following description of the experimental engine, and of the manner of experimenting:

"The engine on which the experiment was carried out was one of "a pair of compound beam engines built in 1838, and which, at one "time, drove Messrs. Donkin's works. Having long been supplanted "in this work by a larger engine, Messrs. Donkin have retained the "old engines in their place for experimental purposes, and have modi- "fied them in various ways, to enable trials to be carried out under "different conditions. In the case of the experiments of which we "are about to speak, the low-pressure piston, etc., of one engine was "disconnected and the high-pressure cylinder was fitted with suitable "double slide valves, so that the engine could be driven as an ordi- "nary non-condensing engine, at different degrees of expansion. The "cylinder is $7\frac{5}{16}$ inches in diameter, and 2 feet $2\frac{1}{8}$ inches stroke,

"and is steam-jacketed, the cylinder being let into the jacket, and "the joint made with iron cement. The steam casing was proved to "be perfectly steam-tight, and the cylinder and piston were in good "order and free from leakage when the experiments were made. "The steam passages are cast on the cylinder, and the slide is near "the top, so that the passage leading to the bottom of the cylinder is "very long. Thus the capacity of the top passage is 60 cubic inches, "and the clearance space above the piston 21 cubic inches, making a "total clearance at the top of 81 cubic inches; while at the bottom "the capacity of the passage is 155 cubic inches, and the clearance "below the piston 34 cubic inches, making a total clearance space at "the bottom of 189 cubic inches. The top clearance spaces thus "amount to 7·4 and the bottom clearance spaces to no less than 17·2 "per centum of the volume swept through by the piston, the mean "clearance being thus 12·3 per centum.

"As we have said, the engine on which the experiments were made "is one of a pair, and advantage was taken of this fact to obtain a "constant resistance in the following way: The slide valve of the fel- "low engine was taken out and that engine was made to draw air "into its cylinders and force it out again through two pipes, the ends "of which were furnished with cocks, so that the resistance to both "in-going and out-coming air could be regulated at pleasure. Self- "acting lubricators were fitted to both cylinders, and in this way it "was rendered possible to obtain a constant resistance; in fact the "power thus absorbed was so nearly absolutely constant that a dif- "ference of but 3 per centum existed between the maximum and "minimum indicator cards in any given experiment. The revolutions "made by the engine were registered by a counter, and the indicator "diagrams were taken by a pair of Richards' indicators driven from "the parallel motion direct, and the springs of which had been care- "fully tested before being used.

"The amount of water used in each experiment was carefully ascer- "tained by weighing it, special provisions being made to secure accu- "racy. As the steam-jacket extended round the large cylinder (the "piston of which was, as we have said, disconnected), and as there "was a considerable length of 2 inches steam pipe between the engine "and the boiler, it was desirable to ascertain what quantity of steam "was condensed in the pipe and jacket when the engine was still. "This was accordingly tried for five hours at a time on two occasions,

"and the quantity condensed was found to be 30 pounds per hour in "each case."

The area of the piston-rod of the steam-cylinder is not given, but I have assumed it at the usual proportion, and having deducted it, find the net area of the steam-piston to be 41·6 square inches. The stroke of that piston being 2·1771 feet, its space displacement per double-stroke or per revolution of the crank, is 1·25787 cubic feet, to which adding the spaces at the top and bottom of the cylinder in clearances and steam passages, namely, 0.17625 cubic foot, we have for the bulk of steam exhausted from the cylinder per double-stroke of piston, 1·41412 cubic feet. The calculations in the following Table have been made for the above quantities.

The principal objection to these experiments as regards accuracy, is the shortness of their duration; the time in two of them being only two hours and 45 minutes, in two others, three hours; and in the remaining two, four hours and 30 minutes. It is very difficult to leave the water-level in a boiler at the end of an experiment just where it was at the beginning, and with the water at the same temperature and having the same pressure upon it; yet the accuracy of the results depends on such equality, for the quantity of water pumped into the boiler is the measure of the cost of the various effects produced, and if the area of the water-surface in the boiler be proportionally large, much error may occur from this source, and, being absolute, will be relatively so much the greater as the duration of the experiment is so much the shorter.

The number of indicator-diagrams taken in the different experiments, and from which the steam pressures in the cylinder are ascertained, was 38 in each of the experiments in columns A and B of the following Table, 22 in each of the experiments in columns C and D, 26 in the experiment in column E, and 24 in the experiment in column F. On their correctness depends the correctness of the powers computed from them. As regards these diagrams, data is wanting in three important particulars, namely, the back pressure against the piston, the pressure required to work the engine, *per se*, or unloaded, and the height of the barometer. I have supplied, in all three cases, the omission from my own experience with similar engines, assuming the back pressure to be 1·3 pounds per square inch of piston above the atmosphere or 16 pounds per square inch above zero; the pressure

required to work the unloaded engine or to overcome its friction, *per se*, 2 pounds per square inch of piston; and the height of the barometer at 29·92 inches of mercury.

Explanation of the Following Table Containing the Data and Results of the Experiments.

The data and results of the experiments will be found in the following table, in columns lettered from A to F, both inclusive. The quantities, for facility of reference, have been grouped and the lines containing them numbered.

Line 1, gives the duration of the experiments in hours and minutes.

Engine.—Line 2, contains the steam-pressure in the boiler. This pressure was constant in all the experiments at 45 pounds per square inch above the atmosphere.

Line 3, contains the mean number of double strokes of piston, or revolutions of crank, made per minute during the experiment, as given by a self registering counter.

Line 4, contains the number of pounds of feed-water pumped into the boiler per hour.

Line 5, contains the number of pounds of steam condensed per hour in the steam-pipe and steam jacket by external radiation alone; the temperature of the steam being that (292¼ degrees Fahrenheit) normal to its boiler pressure of 45 pounds per square inch above the atmosphere, or 59·7 pounds per square inch above zero; and the temperature of the air surrounding the steam-pipe and steam-jacket being that given on line 9.

Line 6, contains the number of pounds of water of condensation drawn from the steam-jacket of the cylinder per hour, and is inclusive of the quantity on line 5 in the experiments (columns A, C and E), in which steam was used in the jacket.

Line 7, gives the per centum which the quantity on line 6 is of the quantity on line 4.

Lines 8 and 9, contain the mean temperatures in degrees Fahrenheit of the external atmosphere and of the engine-room during the experiments.

Steam-Pressures in Cylinder per Indicator.—The quantities on lines 10 to 15, both inclusive, are the means of the indicator-diagrams with the exception of the quantity on line 12 for which the back-pressure against the piston was assumed at 1·3 pounds per square

inch above the atmosphere, and the atmospheric pressure was assumed at 14·7 pounds per square inch above zero, making a total of 16 pounds per square inch of piston above zero. The quantity on line 14 is the sum of those on lines 12 and 13, and the quantity on line 15 is the remainder of that on line 13 after deducting 2 pounds per square inch of piston for the pressure required to work the unloaded engine. The quantities on lines 10 and 11 are the pressures given in the original data in pounds per square inch of piston above the atmosphere, plus the assumed atmospheric pressure of 14·7 pounds per square inch.

POWER—*Absolute.*—Line 16, contains the gross effective indicated horse-powers developed by the engine, that is to say, the power corresponding to the area of the indicator diagram. It is computed from the speed of piston on line 3 and the pressure on line 13; and represents the work done by the steam in overcoming the external load and its friction, and the friction of the engine, *per se*; but is exclusive of the work done in overcoming the back-pressure.

Line 17, contains the total horse-powers developed by the engine computed from the speed of piston on line 3 and the pressure on line 14. This power represents the whole work done by the steam, both in overcoming the back-pressure, the frictions of the external load and of the engine *per se*, and in moving the external load.

Line 18, contains the net horse-powers developed by the engine, calculated from the speed of piston on line 3, and the pressure on line 15. This power represents the external work done by the steam, and in overcoming the friction of that work; but is exclusive of the work done in overcoming the back-pressure and the friction of the engine, *per se*.

POWER—*Economic.*—Lines 19, 20 and 21, contain respectively the cost of the gross-effective, total, and net horse-power in pounds of feed-water (or pounds of steam) consumed per hour. These quantities are the quotients of the division of the quantity on line 4 by those on lines 16, 17 and 18.

CONDENSATION.—Line 22, contains the number of pounds of steam discharged per hour into the atmosphere from the cylinder, calculated from the pressure of the steam at the end of the stroke of the piston, line 11. This is not necessarily the whole quantity of steam discharged into the atmosphere from the cylinder; for should there be

any water of condensation in the cylinder when the exhaust port is opened at the end of the stroke of the piston, it will be vaporized and pass into the atmosphere during the exhaust stroke under the lessened pressure and by its contained heat and the heat in the metal of the cylinder.

Line 23, contains the number of pounds of steam condensed per hour in the boiler and cylinder to furnish the heat transmuted into the total power developed by the engine. It is calculated for the thermal equivalent of one pound of water at 32 degrees Fahrenheit raised one degree Fahrenheit in temperature for every 772 foot-pounds of work done by the engine.

Line 24, contains the sum of the quantities on lines 22 and 23, and it is all of the steam evaporated in the boiler (line 4) which can be accounted for by means of the indicator. Of course, none of the steam condensed by external radiation from the steam-pipe and cylinder surfaces, or within the cylinder by any cause other than the production of the power, is, or can be, included. The quantity on line 24 will always be less than that on line 4, unless superheated steam raised to a sufficiently high temperature to prevent condensation, be employed.

Line 25, contains the per centum which the difference of the quantities on lines 4 and 24 is of the quantity on line 4, and shows the per centum of the weight of steam evaporated in the boiler which is condensed by external radiation from the steam-pipe and cylinder surfaces, and within the cylinder by any cause other than the production of the power.

The sum of the quantities on lines 24 and 6 being subtracted from the quantity on line 4, the remainder, expressed in per centum of the quantity on line 4, is given on line 26. The quantity on line 26, therefore, is only for experiments A, C and E, in which steam was used in the jacket, and shows, in per centum of the weight of steam evaporated in the boiler, the weight of steam condensed within the cylinder by causes other than the production of the power.

The sum of the quantities on lines 24 and 5 being subtracted from the quantity on line 4, the remainder, expressed in per centum of the quantity on line 4, is given on line 27. The quantity on line 27, therefore, is only for experiments B, D and F, in which steam was not used in the jacket, and shows, in per centum of the weight of steam evaporated in the boiler, the weight of steam condensed within the cylinder by causes other than the production of the power.

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE ON A STEAM-JACKETED NON-CONDENSING STEAM-ENGINE AT THE FACTORY OF B. DONKIN & CO., LONDON, USING STEAM OF THE SAME BOILER PRESSURE WITH AND WITHOUT STEAM IN THE JACKET, WITH AND WITHOUT THROTTLING, AND WITH DIFFERENT MEASURES OF EXPANSION.

No. of Line.			Steam cut off at $\frac{3}{8}$ of the stroke of the piston, and not throttled.		Steam cut off at $\frac{2}{3}$ of the stroke of the piston, and not throttled.		Steam cut off at $\frac{2}{3}$ of the stroke of the piston, and much throttled.	
			Steam in Jacket.	No ste'm in Jacket.	Steam in Jacket.	No ste'm in Jacket.	Steam in Jacket.	No ste'm in Jacket.
			A	B	C	D	E	F
1		Duration of the experiment in hours and minutes	4·30	4·30	2·45	2·45	3·00	3·00
2	ENGINE.	Steam pressure in boiler, in pounds per square inch above the atmosphere	45·	45·	45·	45·	45·	45·
3		Number of double strokes of engine's piston made per minute	48·31	44·81	51·17	46·82	45·63	47·00
4		Pounds of feed-water pumped into the boiler per hour	361·244	354·155	562·145	556·364	334·667	419·667
5		Pounds of steam condensed per hour in the steam pipe and steam-jacket, by external radiation	30·000	....	30·000	....	30·000	....
6		Pounds of water of condensation drawn from the steam-jacket of the cylinder per hour	53·333	....	47·636	....	47·000	....
7		Per centum of the feed-water pumped into the boiler drawn from the steam-jacket as water of condensation	14·76	....	8·47	....	14·04	....
8		Temperature, in degrees Fahrenheit, of the external atmosphere	43·	35·5	33·	32·	37·	35·5
9		Temperature, in degrees Fahrenheit, of the engine-room	62·	62·5	74·75	61·	73·5	63·00
10	Steam Pressures in Cylinder per Indicator.	In pounds per square inch above zero, at commencement of stroke of piston	56·70	53·70	59·20	55·70	39·70	41·70
11		In pounds per square inch above zero, at end of stroke of piston	22·70	21·20	41·70	40·20	25·20	28·70
12		In pounds per square inch above zero, against the piston during its stroke	16·00	16·00	10·00	16·00	16·00	16·00
13		Mean gross-effective pressure on piston, in pounds per square inch	23·97	19·93	37·31	34·30	17·89	19·35
14		Mean total pressure on piston, in pounds per square inch	39·97	35·93	51·31	50·30	33·89	35·35
15		Mean net pressure on piston in pounds per square inch	22·47	18·43	35·81	32·80	16·39	17·85
16	POWER. Absolute.	Gross-effective horse-powers developed by the engine	6·356	4·902	10·479	8·815	4·481	4·992
17		Total horse-powers developed by the engine	10·599	8·837	14·411	12·927	8·488	9·120
18		Net horse-powers developed by the engine	5·958	4·533	10·058	8·430	4·105	4·605
19	POWER. Economic.	Pounds of feed-water pumped into the boiler per hour per gross-effective horse-power	56·835	72·247	53·645	63·116	74·686	84·068
20		Pounds of feed-water pumped into the boiler per hour per total horse-power	34·083	40·076	39.008	43·039	39·428	46·016
21		Pounds of feed-water pumped into the boiler per hour per net horse-power	60·632	78·128	55·890	65·998	81·527	91·133
22	CONDENSATION.	Pounds of steam discharged per hour from the cylinder, calculated from the pressure of the steam at the end of the stroke of the piston	236·808	205·678	448·781	396·584	247·294	288·547
23		Pounds of steam condensed per hour in boiler and cylinder, to furnish the heat transmuted into the total power	29·924	24·950	40·687	36·497	23·964	25·749
24		Sum of the above two quantities; or weight of steam per hour accounted for by the Indicator,	266·732	230·628	489·468	433·081	271·258	314·296
25		Per centum of the steam evaporated in the boiler not accounted for by the Indicator	26·16	34·88	12·93	22·16	18·95	25·18
26		Per centum of the steam evaporated in the boiler not accounted for by the Indicator & st'm-jacket	11·40	....	4·45	....	4·90	....
27		Per centum of the steam evaporated in the boiler not accounted for by the Indicator and external radiation	....	26·41	....	16·77	....	19·76

Discussion of the Results.

The experiments determine for the experimental conditions:

1st. The relative economic efficiency under various initial, mean total, and back-pressures in the cylinder, of the two measures of expansion used, namely, those due to cutting off the steam at $\frac{3}{8}$ and at $\frac{2}{3}$ of the stroke of the piston from the commencement, and they determine it for the two cases of with and without steam in the jacket.

2d. The relative economic efficiency of the steam-jacket for various initial, mean total, and back-pressures, in the cylinder; and for the two measures of expansion with which the steam is used.

3d. The quantity of steam condensed in the jacket to furnish the heat imparted to the cylinder, and acting for the prevention of the condensation of steam in the cylinder. This quantity of steam thus condensed in the jacket is exclusive of the quantity therein condensed by external radiation.

4th. The quantity of steam condensed in the cylinder by causes other than those due to external radiation and to the production of the power.

Of the Relative Economic Efficiency of the Two Measures of Expansion due to Cutting off the Steam at three-eighths and at two-thirds of the Stroke of the Piston.

The relative economic efficiency obtained from cutting off the steam at $\frac{3}{8}$ and at $\frac{2}{3}$ of the stroke of the piston from the commencement, varies greatly according to the conditions of the cylinder pressures. For a correct engineering comparison, the cost in pounds weight of steam consumed per hour to produce the total horse-power developed by the engine should be employed; because that power includes all the resistances of what kind soever overcome by the steam admitted to the cylinder. This comparison by total horse-power supposes either no back-pressure against the piston, or that the back-pressure with the two measures of expansion employed is the same per centum of the total pressure, which corresponds to the case of equal net powers developed in the same cylinder with equal speed of piston but with unequal initial pressure, the initial pressure being carried as much higher with the shorter cut-off as is necessary to make the net pressure on the piston equal.

Taking then the case of column A in the Table, in which the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, with the boiler steam present

in the jacket, we have the cost of the total horse-power 34·083 pounds of feed-water per hour (line 20 of the Table); while in the cases of columns C and E, in which the steam was cut off at $\frac{2}{3}$ of the stroke of the piston, with the boiler steam also present in the jacket, we have the cost of the total horse-power 39·008 and 39·428 pounds of feed-water per hour, the mean of which is 39·218 pounds; consequently, the economic efficiency when cutting off at $\frac{3}{8}$ of the stroke of the piston was $\frac{39{\cdot}218 - 34{\cdot}083 \times 100}{39{\cdot}218} = 13{\cdot}09$ per centum greater than when cutting off at $\frac{2}{3}$ of the stroke of the piston, assuming the cost for the latter as unity.

If, however, the comparison be made for the cost of the net horse-power instead of for the total horse-power, in pounds of feed-water consumed per hour, a very different result will be obtained. Now, the net horse-power is that portion of the total horse-power developed by an engine which is commercially valuable, that is to say, the portion which moves the external load; and the results of the comparison with it, determines the practical value of the different points of cut-off. Taking, then, the case of column A, as before, cutting off at $\frac{3}{8}$ of the stroke of the piston with the boiler steam in the jacket, we have 60·632 pounds of feed-water consumed per hour per net horse-power (line 21); while in the case of column C, with the boiler steam in the jacket, but cutting off at $\frac{2}{3}$ of the stroke of the piston, we have only 55·890 pounds of feed-water consumed per hour for the cost of the net horse-power, so that the previous economy in favor of the $\frac{3}{8}$ cut-off is actually reversed, becoming $\frac{60{\cdot}632 - 55{\cdot}890 \times 100}{55{\cdot}890} = 8{\cdot}48$ per centum in favor of the $\frac{2}{3}$ cut-off, assuming the cost with the latter at unity as before. Nevertheless, if, instead of making this comparison for the case of column C, we make it for the case of column E, in which the same boiler-steam is used in the jacket, and the same point of cutting off is employed in the cylinder, but in which the relation of the back-pressure to the total pressure is very different, we obtain a very different result, the cost of the net horse-power rising to 81·527 pounds of feed-water per hour, and the economic efficiency when cutting off at $\frac{3}{8}$ of the stroke of the piston, becoming $\frac{81{\cdot}527 - 60{\cdot}632 \times 100}{81{\cdot}527} =$ 25·63 per centum greater than when cutting off at $\frac{2}{3}$ of the stroke of

the piston. In the case of column A, the back-pressure (line 12) against the piston was 40·03 per centum of the total pressure (line 14), while in the case of column C it was 31·18 per centum, and in the case of column E 47·21 per centum. A slight consideration will show how completely this relation of the back-pressure to the sum of the friction and total pressures, and not the Mariotte law, governs the economy in the practical steam-engine of different measures of expansion. The shorter the cut-off, with a given initial pressure, the smaller is the mean total pressure; and the longer the cut-off, the larger is the mean total pressure; and we can easily suppose the cut-off so short that the mean total pressure will be but a little above the sum of the friction and back-pressures, most of the steam used being in this case expended in overcoming resistances of no commercial value; while with a long cut-off with its large mean total pressure so much less a portion of the steam will be expended in overcoming the non-commercial resistances, that the less measure of expansion will give actually greater economic results than the large measure of expansion, as is practically illustrated in these experiments, the sum of the back-pressure and friction-pressure of the engine, *per se*, being constant. Thus it is seen that, the practical economy for the net or commercial horse-power, due to different measures of expansion, depends mainly on the relation between the mean total pressure upon the piston, and the sum of the back-pressure and friction of the engine, *per se:* and that this economy is not at all inferable from the Mariotte law, but is a practical result to be obtained from practice alone, and will vary with every variation in the practical conditions.

In the case of our experimental engine the waste spaces in the clearances and steam-passages at the ends of the cylinder were about double of the average in practice, and this excess operated against the shorter cut-off. With each reduction of these spaces, the shorter cut-off becomes relatively more economical, but in a subordinate degree, the great cause of the discrepancy being the different proportions of the mean total pressure to the sum of the friction and back-pressures. It must be remarked here, too, that under the experimental condition of the same boiler-pressure in the jacket, that condition operates more favorably for the shorter than for the longer cut-off, by the greater difference between the temperature in the jacket and in the cylinder, due to the less mean total pressure with

the shorter cut-off: but, under the actual experimental conditions, the difference in the temperature of the mean total pressure in the different experiments was not sufficiently great to produce any practical difference in the economic result.

The preceding discussion was for the condition of steam in the jacket, but experiments B, D and F, allow the comparison of the relative economic efficiency of using steam with the measures of expansion due to cutting off at $\frac{3}{8}$ and at $\frac{2}{3}$ of the stroke of the piston to be ascertained for the condition of no steam in the jacket. Here, too, the comparison should be made for the cases of equal mean total pressure and of different mean total pressure. For the former case, we can compare the cost of the total horse-power in pounds of feed-water consumed per hour in column B, with that in column F, the mean total pressure (line 14) being almost exactly the same in both.

In column B, cutting off at $\frac{3}{8}$ of the stroke of the piston, the total horse-power cost 40·076 pounds of feed-water per hour, while in column F it cost 46·016 pounds, showing an economy of $\frac{46{\cdot}016 - 40{\cdot}076 \times 100}{46{\cdot}016} = 12{\cdot}91$ per centum for the shorter cut-off, or almost exactly the same as when steam was used in the jacket. But in the case of column D in which the mean total pressure was much higher than in column B, the total horse-power cost only 43·039 pounds of feed-water per hour, making the economy when cutting off at $\frac{3}{8}$ of the stroke of the piston only $\frac{43{\cdot}039 - 40{\cdot}076 \times 100}{43{\cdot}039} = 6{\cdot}88$ per centum greater than when cutting off at $\frac{2}{3}$ of the stroke of the piston. Thus, it appears that the relative economic efficiency of different measures of expansion in the case when steam is not used in the jacket, depends, even for the total horse-power, on the absolute mean total pressure in the cylinder, the greater this pressure the more the economy; another very important practical modification for the abstract Mariotte law.

As, under the condition of steam in the jacket, so, under the condition of no steam in the jacket, the relative economic efficiency of the two measures of expansion is easily reversed by difference in the ratio of the mean total pressure to the sum of the friction and back-pressures; for example: comparing, for columns B and D, the cost of the net horse-power in pounds of feed-water consumed per hour, we

have for column B, cutting off at $\frac{5}{8}$ of the stroke of the piston, 78·128 pounds; and for column D, cutting off at $\frac{2}{3}$ of the stroke of the piston, 65·998 pounds; or $\frac{78{\cdot}128 - 65{\cdot}998 \times 100}{65{\cdot}998} = 15{\cdot}52$ per centum greater economy for the long cut-off instead of 12·91 per centum against it, as in the comparison for the total horse-power; while for column F, cutting off also at $\frac{2}{3}$ of the stroke of the piston, the cost of the net horse-power rises to 91·133 pounds of feed-water per hour, showing an economy for the shorter cut-off of $\frac{91{\cdot}133 - 78{\cdot}128 \times 100}{91{\cdot}133} =$ 14·27 per centum. Thus, the economic result, when no steam is used in the jacket, depends not only on the measure of expansion, and on the absolute mean total pressure, but also on the ratio of the mean total pressure to the sum of the friction and back-pressures.

The results of these experiments fully confirm the results of those made by the writer on the economy of using steam with different measures of expansion, vindicating the accuracy of his perceptions and the truth of his deductions.

(To be continued.)

ON THE METHODS OF TESTING STEAM ENGINES;

With a Description of the Trials of the Circulating Pumps on the U. S. S. "Tennessee."

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AND

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[Continued from Vol. lxviii, page 396.]

Independent circulating pumps for marine engines are rapidly gaining favor; being independent of the main engines they can be run at any desirable speed, and as they are generally in duplicate, one can be repaired if necessary, while the other is doing duty.

In addition, they furnish a great safeguard against foundering at sea in case of accident to the main engines. If the pumps were attached to the main engines, the same weight of water could be delivered overboard if the engines could be run at the proper speed, but it must be remembered that it takes the whole power of the boilers to run the engines at the ordinary speed, and that their speed cannot be increased in an emergency, but oftentimes by reducing the speed of

the main engines, the independent circulating pumps can be kept at their maximum; hence their great advantage.

It is not often considered the immense weight of water that the circulating pumps are continually passing through the condenser and overboard. By reference to the experiments it will be seen that at a speed of 97 strokes per minute they were together capable of delivering nearly 1000 tons per hour. In case of an emergency they could be run at 150 strokes per minute, and delivering 1500 tons per hour. This water, which is ordinarily drawn from the sea, may be, by suitable arrangement of pipes, drawn from the bilge and pumped overboard.

The displacement of the "Tennessee" is about 300 tons per foot at load draft. Thus, the 1500 tons of water, if allowed to accumulate during the hour, would be sufficient to cause the ship to settle down in the water 5 feet, supposing she should settle on an even keel, but, if as is usually the case when vessels are foundering, she should commence to settle by the head or stern, probably much less than 1500 tons would be sufficient to sink her.

The following are the dimensions of the Circulating Pumps:

Diameter of steam cylinder,	18 in.
" water "	18 in.
" piston rod,	$2\frac{1}{8}$ in.
Length and breadth of steam port,	5 in. by $1\frac{1}{4}$ in.
" " exhaust port,	5 in. by $2\frac{1}{2}$ in.
Stroke of piston (maximum),	$19\frac{3}{4}$ in.
" " "actual,"	$18\frac{3}{4}$ in.
Width of opening of steam valve,	$\frac{3}{8}$ in.
" " exhaust "	$\frac{3}{8}$ in.
Diameter of auxiliary piston,	5 in.
Stroke " "	$\frac{3}{4}$ in.
No. and diameter of receiving valve,	6–7 in.
No. and diameter of delivery valve.	6–7 in.
Total area of valve openings (6 valves),	171 sq. in.
Ratio of piston area,	$\frac{2}{3}$
Diameter of receiving and discharge nozzles,	15 in.
Distance of centre of pump below water line,	2 ft. 6 in.
Greatest length of pump,	7 ft.
" width of pump,	2 ft. 10 in.
" height of pump,	5 ft.

Fig. 1 shows a section and elevation of the pump.

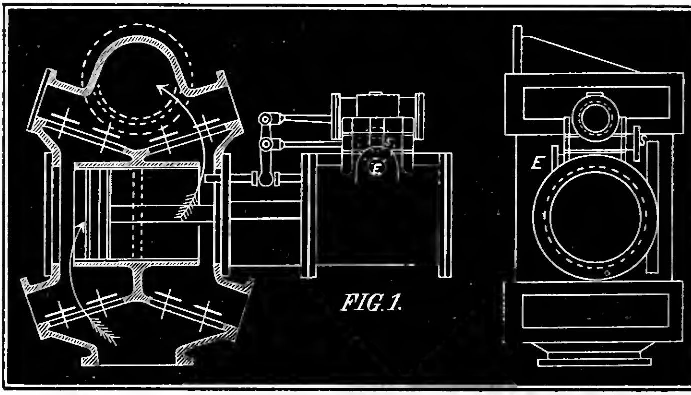


FIG. 1.

There are two of these pumps used for circulating the water through the condenser. Each pump has a separate suction pipe, drawing water through a strainer containing 2000 $\frac{1}{2}$-inch holes, in the bilge of the ship, thence to a Kingston valve, and through 15 feet of 15-in. copper pipe, to pumps, and delivering through 13 feet of 15-inch copper pipe to top of condenser. Here the water from both pumps combines and passes four times through nests of condenser tubes, each nest containing 1978 tubes, $\frac{1}{2}$ inch internal diameter and 7 feet $3\frac{1}{2}$ inches long, and thence through two copper pipes, each 15 inches diameter and 25 feet long, to outboard delivery valves, 24 inches below the surface of the water outside. For the purpose of this experiment a 15-inch copper pipe was bolted to each outboard delivery valve, to carry the water up to a tank, where it could be measured. This pipe had at the lower end a right angle bend of a central radius equal 14 inches, and at the upper end a return bend or goose-neck of the same radius.

The height of the centre of the goose-neck above the surface of the water was 11 feet. An additional length of leather pipe, 4 feet long, was fastened to the goose-neck, in order to carry the stream below the surface of the water in the tank, as it was found that if the stream fell through the air into the tank, so much air would be carried down with it as to render it impossible to know how high the surface of the water in the tank was. When the stream was protected the surface was clear and smooth. It was proposed to measure the water by allowing it to flow through a number of orifices in the bottom of the

tank, each orifice being small enough to allow the water delivered by it to be measured separately at any instant during the experiment; the sum of all the deliveries, or the average of a sufficient number to determine a mean multiplied by the number of orifices, being the amount of water discharged.

Fig. 2 shows a section through the condenser and side of the ship; the arrows showing the course of the water.

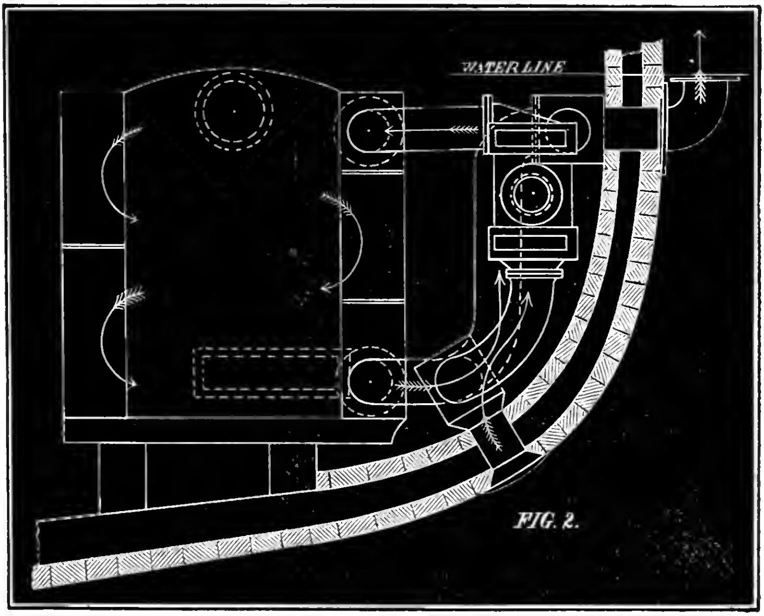


FIG. 2.

There was a separate tank for each outboard delivery, of the following dimensions: diameter, 48 inches; height, 72 inches; thickness, $\frac{1}{4}$ inch.

A hole, 24 inches in diameter, was cut in the bottom, and a composition plate, planed 1 inch thick and 28 inches diameter, was bolted upon the under side. There were drilled in this plate 55 holes, each hole being $1\frac{1}{8}$ inches diameter, and beveled out on the upper side, the depth of the bevel being $\frac{1}{4}$ inch and the angle 30° from the vertical side of the hole. The average distance between the centre of these holes was $3\frac{1}{2}$ inches.

During the experiment a portion of the holes was plugged up with soft pine plugs. During the experiment the pump worked under the

additional load due to the 11 feet head on the standing pipe and the friction of the sides and bends—more than would be required when in regular use at sea.

Fig. 3 shows the arrangement of the tank in reference to the water and side of the ship, and the method of supporting the platform and measuring barrel.

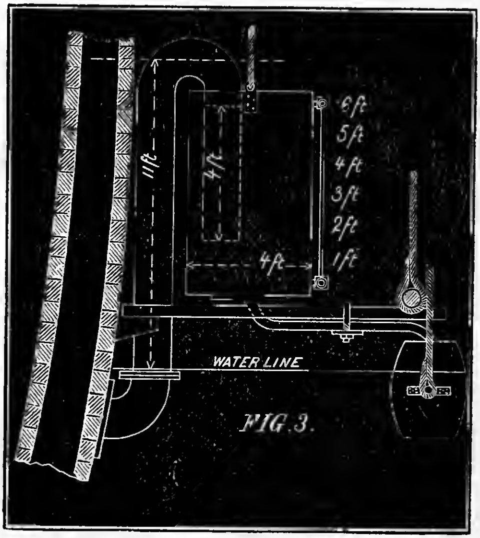


FIG. 3.

It will be seen that the two circulating pumps act entirely as meters of the best construction, for they are sufficiently far below the surface of the water outside the ship to be filled to overflowing at every stroke, and the entire cylinder full of water must be forced through the condenser on the return stroke.

If the rate of these pumps as meters could be determined at various velocities, the volume of water which they were delivering at any time, could be computed.

The following is a description of the apparatus used, and the results obtained in the experiment made previously to the trial of the ship's engines, which has not yet taken place.

It is expected that the trial will take place so soon as the ship comes out of the dock, where she is now receiving new decks and general repairs.

The following experiments were made with the pumps:

1st. To determine the volume of water that would be discharged through the plate in the bottom of the tank, at various heads, and with various numbers of the orifices plugged up.

2d. To determine the volume of water thrown by the pump at various velocities, and the power required.

To determine the amount of water discharged, the pump was run at a velocity required to maintain the desired head in the tank, and the water discharged through one orifice was received in an oil barrel, through a 3-inch iron pipe, one end of the pipe being curved up on a radius of 12 inches and adjusted under an orifice, so that the whole stream would fall directly into it; the other end being curved down to discharge into the barrel. The total length of pipe was 9 feet, and it was so supported that it could be adjusted under any orifice and made fast.

The spaces between the streams were large enough to allow the observer to notice that the whole stream was falling into the pipe, even when under the central orifice.

The barrel to receive the water, the contents having been carefully weighed and measured, was hung so that it could be swung under the end of the pipe at the instant desired, and, when full, dumped.

The time occupied in filling, and the mean head during the interval, were noted, and the experiment repeated a number of times. The position of the pipe was then changed to come under another orifice, and the experiment repeated, and so on until the mean discharge of all the orifices, at various heads, was determined.

The temperature of the sea water during these experiments was 74°, and the saturation, $\frac{1\frac{1}{4}}{32}$ (July 8th, 9th, 10th, 11th).

The barrel contained 6·357 cubic feet.

It was found that when the depth of water over the plate was more than 3 feet, that there was no perceptible difference on the discharge of orifices in various parts of the plate; but that when the head became less than 3 feet, the discharge varied in different orifices, and at different times in the same orifice, under the same head.

This was true, whether all the 55 holes were open, or whether a portion of them were plugged. There could not be detected any difference in the flow, with a head of more than 3 feet, from a difference in the arrangement of the open and closed holes.

The following are the mean results of 49 experiments with a head greater than three feet:

Head of water above plate, in inches.	Cubic feet discharged by each orifice per second.
72·154	·1059
52·660	·0900
41·050	·0796

Fifty-four experiments on less heads than these gave results varying among themselves from zero to twenty-five per cent., and are therefore rejected.

The amount of water discharged from the same orifice at different heads should vary, if there were no causes of disturbance, as the square root of the heads.

The following comparison of the amount discharged actually and computed for the last two cases, by a comparison of the square root of the heads with the amount delivered in the first case, shows that the discharge does vary as the square root of the head, as the differences are within the errors of observation:

Head in inches.	Discharge by Experiment.	By Comparison.
72·154	·1059	———
52·660	·0900	·09019
41·050	·0796	·07964

The co-efficient of contraction being the ratio of volume of water actually discharged to that represented by the area of the orifice multiplied by the theoretical velocity, is

$$C = \cdot 7776.$$

The following table shows the number of cubic feet which will be discharged by each orifice during one hour at various heads, computed from experiments, by a comparison of the square root of the heads. If no opportunity should offer during the trial of the engines to test the capacity of the orifices, it will only be necessary to note the head of water in the tank, and to multiply the corresponding discharge from the table by the number of orifices open, in order to obtain the volume of water discharged per hour at any given instant.

The mean of these volumes (not the volumes corresponding to the mean head) will give the mean discharge of the pump for any number of observations.

The only apparent cause of error will be a change in the density of the water, either from more or less salt, or from a change of temperature; but the errors from these causes will probably be inappreciable.

NUMBER *of cubic feet which will be discharged in one hour from a single orifice at various heads, computed from experiment by a comparison of the square root of the heads.*

Head in inches.	Discharge.	Head in inches.	Discharge.
72	380·8	52	323·7
71	378·2	51	320·6
70	375·5	50	317·4
69	372·8	49	314·2
68	370·1	48	311·0
67	367·4	47	307·8
66	364·6	46	304·5
65	361·9	45	301·1
64	359·1	44	297·7
63	356·2	43	294·3
62	353·5	42	290·9
61	350·6	41	287·4
60	347·7	40	284·0
59	344·8	39	280·3
58	341·8	38	276·7
57	338·8	37	273·1
56	335·9	36	269.3
55	333·0	35	265·6
54	329·9	34	261·7
53	326·8	33	257·9
52	323·7	32	254·5

At the conclusion of the experiments upon the tanks, a series of experiments were made upon the pumps, to determine the volume of water delivered at various velocities, and the power required to work them.

These experiments were made by running one pump at a velocity necessary to maintain a constant head in the tank of nearly five feet, the engineer changing the throttle a little, in response to signals, when the head of water varied. It was found that the head could be maintained within two inches of that desired.

All the experiments were made with the same head of water in the

tank, more or less of the holes being plugged, in order to change the velocity of the pump in the different experiments.

In some of the experiments the pumps were run one hour, but it was concluded that as the head and strokes were so nearly constant, one half hour was sufficient for the latter portion of them.

The number of strokes was counted every 5 minutes during the hour trials, and every $2\frac{1}{2}$ minutes during the half hour trials, during one minute, by a sand glass, which had been tested and found to be correct, and the mean head (when there was any variation) during the minute noted.

Indicator cards were taken every five minutes during the trial, from both the steam and water cylinder of the forward pump.

There were no indicator attachments on the after pump.

The scales of the indicator springs were found by experiment.

The stroke of the forward pump was $18\frac{3}{4}$ inches.

The stroke of the after pump could not be measured.

The following are the means of the result:

FIRST EXPERIMENT.

Which Pump.	Forward.	After.
Number of strokes, . . .	63·46	64·5
Head of water in tank, . .	61·115″	60·75″
Number of holes open, . .	30	30
Cubic feet of water per hour, .	10,530	10,572
Nominal volume of pump, . .	10,930	11,110
Per cent. of do. delivered, . .	96·4	95·2
Actual volume of pump, . .	10,510	
Per cent. of do. delivered . .	100·2	

SECOND EXPERIMENT.

Which Pump.	Forward.	After.
Number of strokes, . . .	79·643	85·458
Head of water in tank, . .	59·8″	61·041″
Number of holes open, . .	40	40
Cubic feet of water per hour, .	13,884	14,003
Nominal volume of pump, . .	13,715	14,720
Per cent. of do. delivered, . .	101·2	95·3
Actual volume of pump, . .	13,190	
Per cent of do. delivered, . .	105.	

THIRD EXPERIMENT.

Which Pump.	Forward.	After.
Number of strokes,	95·8	99·2
Head of water in tank,	61·″	60·9″
Number of holes open,	48	48
Cubic feet of water per hour,	16,828	16,827
Nominal volume of pump,	16,500	17,080
Per cent. of do. delivered,	102·	98·5
Actual volume of pump,	15,870	
Per cent of do. delivered,	106·2	

It would, at first thought, appear impossible that any pump should deliver more water than the actual piston displacement, but it must be remembered that the conditions of these pumps are materially different from those generally tested.

In place of having to suck the water from a tank below, the pump cylinder is 2½ feet below the surface of the water, which would, if the piston were at rest, fill the barrel, and rise 2½ feet above.

The maximum velocity of the water in the suction-pipe is less than 4 feet per second, while the velocity due to a head of 2½ feet is more than 14 feet, leaving a margin of 10 feet velocity corresponding to a head of more than 1½ feet, tending to overflow the pump barrel.

This would account for an amount of water equal to the full displacement of the piston, for it will be seen hereafter that the head necessary to overcome the resistance of the valves and pipes is less than this difference.

To account for the excess of water delivered another cause appears.

The total length of all pipes from the sea to the pump, and thence through the condenser and overboard, is more than 70 feet. These pipes must be filled with a solid column of water, for there are no air vessels on the pump, and there can be no air in the water, except that drawn in through the Kingston valve in the bilge, 20 feet below the surface.

The mean velocity of the water in these pipes, at 100 strokes, is more than 3 feet per second.

When the pump piston has its maximum velocity it is pushing this column of water, but when it reaches the end of its stroke and suddenly stops, hesitating an instant before commencing a return stroke, the long column of water cannot be instantly stopped without burst-

ing all the pipes, but must, as in a hydraulic ram, continue in motion until its momentum is exhausted.

The velocity of 3 feet per second would carry it up about $1\frac{1}{2}$ inches in the standing pipe, if the piston should hesitate long enough.

The total travel of the water might be

$$18\tfrac{3}{4}'' + 1\tfrac{1}{2}'',$$

and the per cent. of piston displacement delivered

$$\frac{18\frac{3}{4}+1\frac{1}{2}}{18\frac{3}{4}}=108.$$

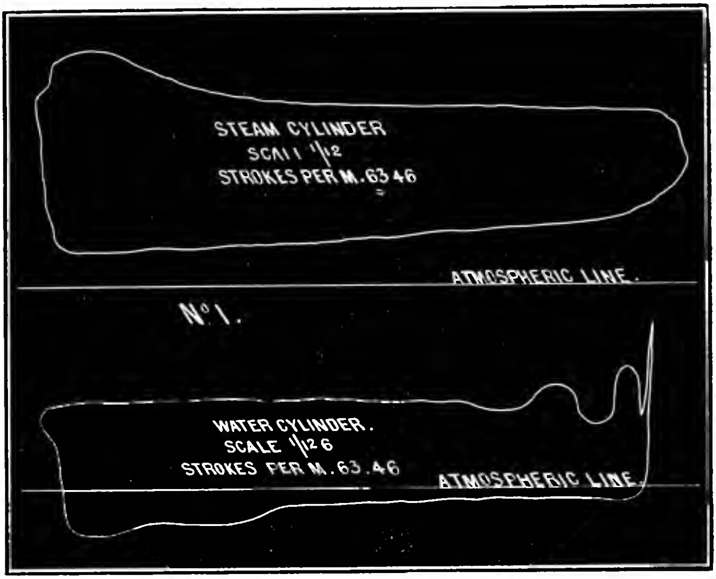
The maximum excess would be, at this speed, 8 per cent., which would be reduced by the resistance of the passages.

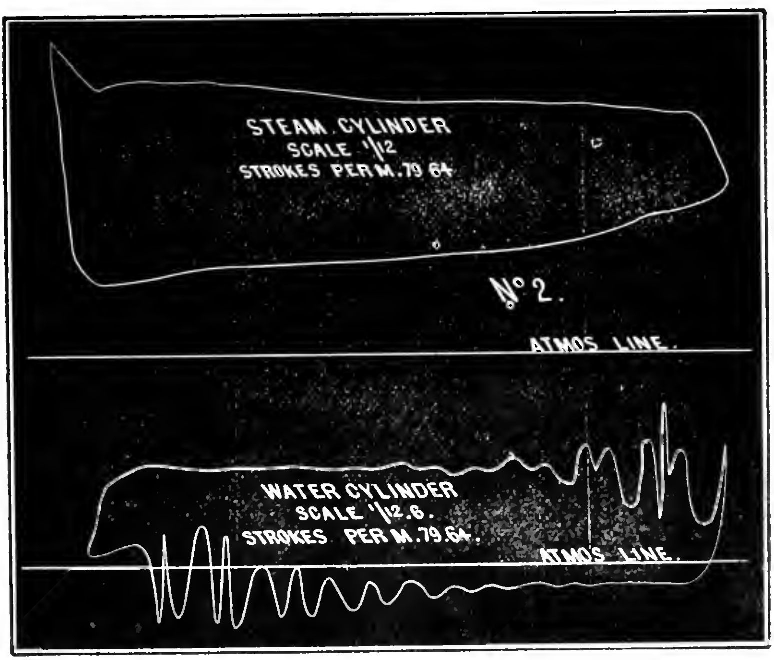
There can be no gain of efficiency from this cause, for although a portion of the water has gone through the pump without effort, when the piston commences its return stroke it will press on the water at rest, or nearly so, which must be set in motion at the expense of the steam.

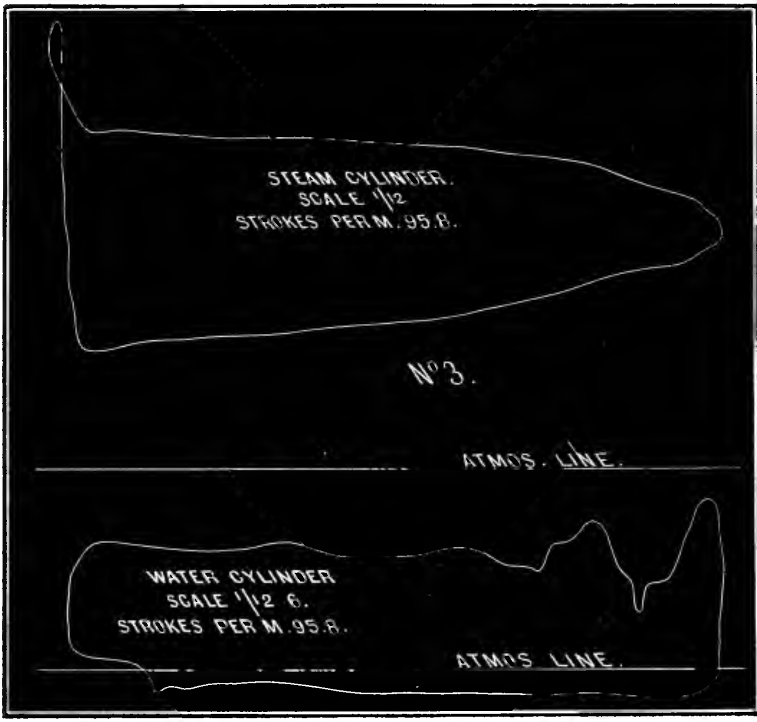
The shape of the indicator cards taken from the water cylinder appears to indicate that, during the first part of the suction stroke, the water was pressing on the piston, as explained above, and that the portion of the stroke through which that action lasts, increases as the pump runs faster, corroborating the measurements and foregoing theory.

The results computed from the indicator cards taken from the forward pump (copies of which are annexed to this paper), are as follows:

Number of strokes, . . .	63·46	79·64	95·8
Steam, mean pressure, . . .	8·6	9·72	10·62
" back " . . .	2·77	6·24	9·34
" total " . . .	11·37	15·96	19·96
Water, mean pressure, . . .	7·118	7·673	8·83
Pressure necessary to work pump, steam pressure less water pressure, . .	1·482	2 049	1·78
	Mean	1·77	
Actual horse-power (one pump),	6·5	11·2	14·7
Actual horse-power at reduced head (one pump),	2·46	4·86	7·1


STEAM CYLINDER
SCALE 1/12
STROKES PER M. 63 46
ATMOSPHERIC LINE.
No. 1.
WATER CYLINDER.
SCALE 1/12 6
STROKES PER M. 63.46
ATMOSPHERIC LINE.


STEAM CYLINDER
SCALE 1/12
STROKES PER M. 79 64
No. 2.
ATMOS LINE.
WATER CYLINDER
SCALE 1/12.6.
STROKES PER M. 79.64.
ATMOS LINE.



APPENDIX.

The following computation of the head in feet, necessary to force the water through the pipes, valves and condenser tubes at the velocity corresponding to sixty strokes of the pump per minute, made previous to the experiment, according to the laws of hydraulics as laid down in Rankine's Civil Engineering, serves to check the accuracy of the experiment, and to show that the power necessary to work a circulating pump on ship board can be very approximately computed when the arrangement of pipes is known :

Assumed velocity of pump, 60 strokes per minute.

	Areas in square feet.	Velocity of Water in feet per second.
Tubes, . . .	2·698	1·028
Pipes, . . .	1·227	2·241
Pump, . . .	1·767	1·562
Valve ports, . .	1·1875	2.324
Strainer holes, . .	1·474	1·872

The losses of head considered are:
1st. Head necessary to give velocity.
2d. " " " overcome friction.
3d. " " " " resistance of bends.
4th. " " " " " " valves.

These have the following values:

To give velocity, . . $h = \frac{v^2}{2g}$.

Tubes, . . .	$h =$ ·0602
Pipes, . . .	" ·2337
Pump barrel, . .	" ·0758
Valve ports, . .	" ·1677
Strainer, . . .	" ·0543
	·5917

To overcome friction $h_2 = F\frac{v^2}{2g}$,
in which F is a factor depending upon the form and material or the passage.

Tubes, . . .	$h_2 =$ ·275840
Pipes, . . .	" ·089280
Pump barrel, . .	" ·000222
Valve ports, . .	" ·001310
Strainer, . . .	" ·004388
	·384040

To overcome resistance in bends, being an amount depending upon the number and abruptness of bends, $h_3 = 1{\cdot}1664$.

To overcome resistance of springs on back of valves:

Area of rubber disc, 50 square inches.
Strength of spring, 45 lbs.
Estimated lift, $\frac{3}{8}$ inch.
Press per square inch, $\frac{9}{10}$ lbs.

Loss of head:

Receiving valve,	$h_4 = 1{\cdot}8$
Delivery "	1·8
	3·6

Friction and bends in external pipe:

$$h_5 = {\cdot}0860.$$

Total resistance at 60 strokes:

$$\begin{aligned} h_1 &= \ {\cdot}591700 \\ h_2 &= \ {\cdot}384040 \\ h_3 &= 1{\cdot}664000 \\ h_4 &= 3{\cdot}600000 \\ h_5 &= \ {\cdot}086000 \\ \hline & \ 6{\cdot}325740 \end{aligned}$$

Total loss from friction at 60 strokes:

$$\begin{aligned} h_1 &= \ {\cdot}59170 \\ h_2 &= \ {\cdot}38404 \\ h_3 &= 1.66400 \\ h_5 &= \ {\cdot}08600 \\ \hline & \ 2{\cdot}72574 \end{aligned}$$

Total loss from friction at 63·46 strokes:

$$\frac{(63{\cdot}46)^2}{(60)^2} \times 2{\cdot}72574 = 3{\cdot}049$$

Resistance of valves, . . .	3·600
Statical head in pipe, . . .	11·000
Computed head equivalent to resistance, .	17·649
Experimental head equivalent to resistance, being mean pressure + height of water above the pump, . . .	16·460
Difference, ...	1·278
Error of computed resistance in per cent. of actual resistance, . . .	$6\frac{3}{4}$

This error probably arises from the valves not lifting as much as $\frac{3}{8}$ inches, and therefore the springs on the backs of the receiving and delivery valves not offering the resistance stated.

TEST TRIAL OF THE LYNN PUMPING ENGINE.

SECOND REPORT OF THE BOARD OF ENGINEERS, TO THE PUBLIC WATER BOARD OF LYNN, MASS.

[Continued from Vol. lxviii, page 414.]

MEASURES OF CAPACITY OF PUMP.

The overflow from the stand-pipe at the reservoir was conveyed by a wooden trunk into a weir box 15 feet long, 6 feet wide and 4 feet 6 inches deep. The weir was at the opposite extremity from the trunk. Its crest was 2·11¾ feet above the bottom of the box, and 3·73 feet wide, and placed centrally in the end of the box. That the water should approach the weir with as uniform flow as possible, two racks covered with wire cloth were placed between the trunk and the weir. The arrangement of weir and mode of taking heights of water were like those adopted by Mr. Francis in his "Lowell Hydraulic Experiments." The readings were every 2½ minutes, and as the heights varied but little they have been averaged as giving a result sufficiently near. The discharges have been calculated by Mr. Francis' Tables and the correction for velocity of approach from his formula.

The readings were taken from 3 P. M. to 6 P. M., December 10, and from 3 P. M. to 6 P. M., December 11. Readings would have been taken the 12th, but the filling of the reservoir by the pumping disturbed the supports of the weir box.

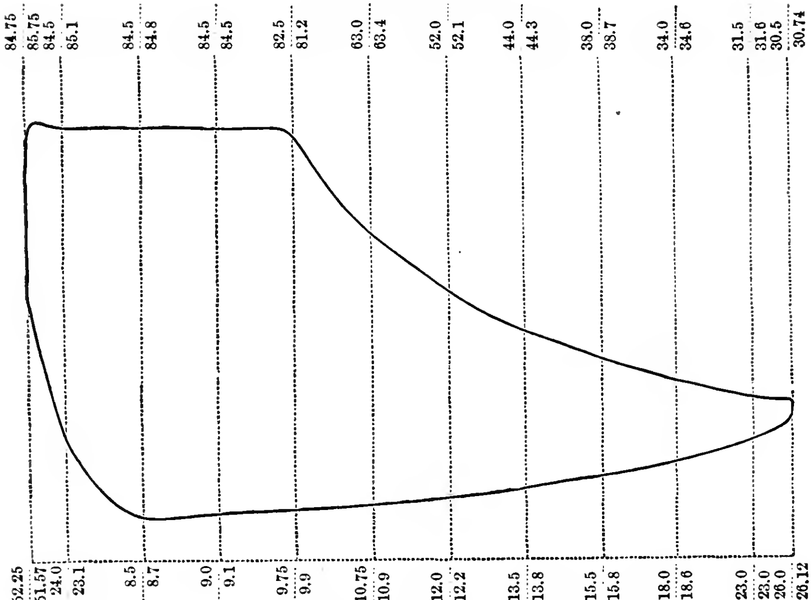
The average height on the 10th was	0·743	
" " " 11th was	0·739	
Discharge from 3 P. M. to 6 P. M., December 10th	7·666 cubic feet per second.	
" " " " " 11th	7·606 " " "	
Leak of weir measured and estimated	0·0092 " " "	
Revolutions of engine during 3 hours, from 3 P. M. to 6 P. M., Dec. 10th	3,303.	
" " " " " " " 11th	3,314.	
Capacity of pump by weir, measured December 10th		187·49 galls.
" " " " " 11th		185·41 "
Average	186·45	
Add for leak at weir	·23	186·68 "
Measured capacity		194·37 "

$$\frac{186.68}{194{\cdot}37} = {\cdot}9601.$$

Loss of action of pump as given in the first report, 4 per cent.

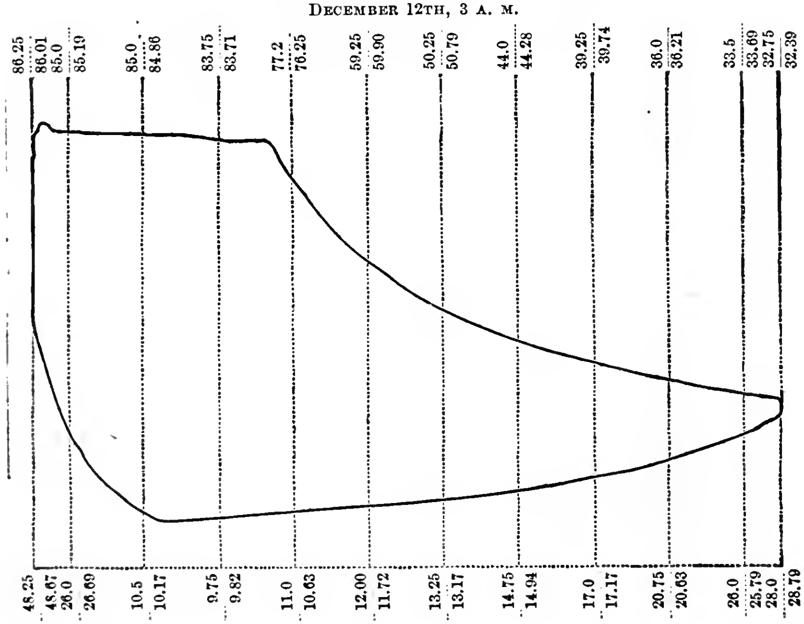
HIGH PRESSURE CYLINDER—TOP.

DECEMBER 11TH, 6 A. M.



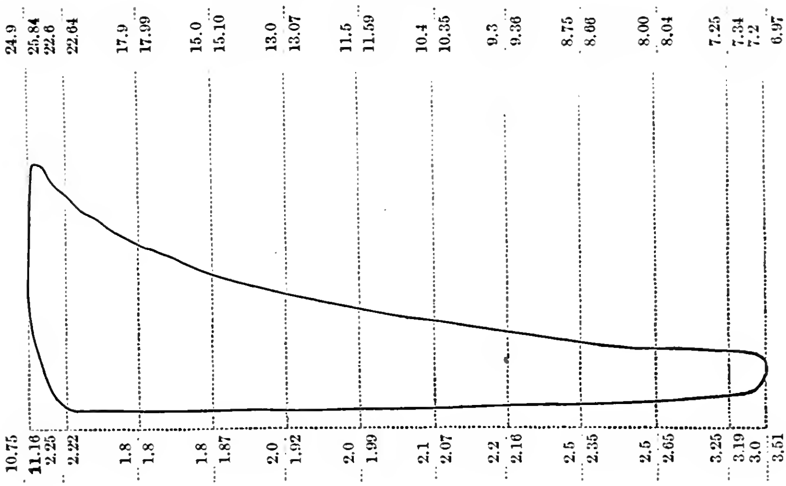
HIGH PRESSURE CYLINDER—BOTTOM.

DECEMBER 12TH, 3 A. M.



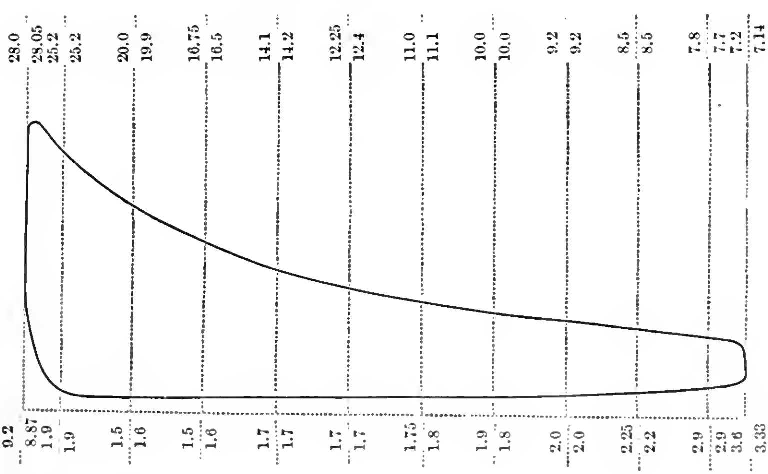
LOW PRESSURE CYLINDER—TOP.

DECEMBER 11TH, 11 P. M.—AND AVERAGES.



LOW PRESSURE CYLINDER—BOTTOM.

DECEMBER 12TH, 2. A. M.—AND AVERAGES.



The cards, as given in the cuts, are representations of cards taken by the indicators. The figures to the left of the lines show the pressures as measured by the scales of lbs.—the figures to the right of the lines, the average pressures on the different ordinates taken from the table of indicator cards.

The readings of the barometer at the engine house were :—

9 A. M.,	December	10th	30·10 inches.
5 "	"	11th	30·30 "
3 P. M.,	"	12th	29·68 "

with nearly a gradual rise and fall.

The records at the signal station, Boston, were:—

7.58 A. M.,	December	10th	30·070
7 "	"	11th	30·276
2 P. M.,	"	12th	29·658

Records of gauge—

	Extremes.	Average.
Vacuum	$27\frac{3}{4}$ to $28\frac{1}{4}$ in.	28 in.
Steam gauge in engine room	65 to 72 lbs.	$70\frac{1}{2}$ lbs.
	(Corrected.)	
" on boiler No. 1	$69\frac{1}{2}$ to $75\frac{1}{2}$ lbs.	$73\frac{1}{2}$ "
" " No. 2	70 to 76 "	74 "
Water gauge in engine room	63·6 to 64·6	64·20

This last gauge was that employed to determine the pressure on the water piston, and it will be seen by reference to our first report that reducing the height of the gauge above the average height of water in the well to pounds, and estimating friction in this lower portion of the main at 1 pound; the pump piston is credited with a load of 73·41 pounds per square inch. During the night of December 10-11 and 11-12 a number of cards were taken by Mr. Hermany from the centre of the pump by a Hopkinson indicator. The average pressure, as shown by the cards taken December 10-11, was 73·66 lbs., and December 11-12, 72·75 lbs., of which the average will be at little less than the load estimated in our calculations of duty.

The average length of stroke from the cards, before the cut-off on the high-pressure cylinder was at top	0·337	of stroke.
At bottom	0·325	"
The average closing of exhaust was in high-pressure cylinder, top	0·858	"
Bottom,	0·841	"
Low " Top	0·938	"
Bottom,	0·940	"

READINGS OF THERMOMETERS.

	Extremes.	Average.
Steam in engine connection	321° to 326°	324°
Smoke in boiler flue	310 to 350	333
Feed water from measuring cask	91 to 97	95
" " " donkey connection	91 to 98	95
Condensed water at its discharge into pump-well	88 to 92	91

WELL.

Pump well	40 to 42	41
Air outside engine house	24 to 38½	32
	ft. in. ft. in.	ft. in.
Water in well—depth	7 10½ to 8 1	7 11¾
Depth of overflow of stand-pipe at reservoir	6 inches.	

Referring to the last column of preceding table, it will be seen that at 11 A. M., December 10th, the average level of the water in the boilers was 0., whilst at 3 P. M., Dec. 12th, it was + 3-16 inch, or about 143 lbs. of water in excess in the boilers at the close of the trial over what it was at the commencement. It was discovered Dec. 11th that there was a small leak from the boilers through the blow-off pipe, which continued throughout the trial, and this leak was found, by catching it in a pail and weighing, to be at the rate of 22 lbs. per hour. 22 lbs.×52 hours,+143 lbs.=1,287 lbs. These 1,287 of water were raised from 95°, the average temperature of the feed, to 324°, the average observed temperature of the steam, which, on the basis of the evaporation during the trial, from 95° to 1,179°, would require 317 lbs. of coal. No account of this small item was taken in our estimate of duty.

At the close of the trial for duty and capacity, an experiment was made to determine the quantity of steam condensed in the jackets of the steam cylinders. The return pipe to the boiler was disconnected and the water as condensed in the jackets was allowed to drip into a pail, and as the pail was full the time was noted and contents weighed. The rate of condensation was found to be nearly uniform, and the quantity condensed in 56½ minutes, 69 lbs. at 98°, or if referred to the 52 hours duration of the trial, 3,810 lbs. were during that time condensed in the jackets.

In conclusion, the records now submitted in this our second report, without any deductions or inferences therefrom, will be found full and sufficient to enable any one interested in and conversant with such matters to estimate the work done at engine and pump, the

friction of rising main, and the evaporation of water per pound of coal, or per pound of combustible, at any standard of temperature; thus affording means of comparison with former experiments on pumping engines; and at the same time presenting in a preservable form data which we trust will be valuable for future reference.

W. E. WORTHEN, JAS. P. KIRKWOOD,
J. C. HOADLEY, CHAS. HERMANY,
JOSEPH P. DAVIS.

New York, June 1st, 1874.

APPENDIX.

First Report of the Board of Engineers on the Test Trial of the Pumping Engine at Lynn, Mass.

Gentlemen:—Agreeably to your request, we have made a test trial of the pumping engine connected with your works, and now respectfully present this our first report.

The character of the engine being entirely different from that prescribed in the original specifications, it seemed to us that the manner of conducting the experiment, and of determining the capacity and duty of the engine, was left without restriction to our judgment, and in this view your chairman concurred.

As the pumping engine at Lowell is very similar to yours in construction and performance, we have followed the modes of test that were adopted at the late trial there.

The engine was started at 8.50 A. M., December 10, 1873, but the test was not considered to have commenced till 11 A. M., and it was concluded at 3 P. M., December 12, making the duration of the trial fifty-two hours, without stop. The engine at the conclusion of the test continued its work, the fires and water in the boilers being kept as uniform as possible, and the duration of the experiment was established by inspection of the firing as shown on the coal profile plot. The capacity of the pump was determined by weir measures at the reservoir—three hours, from 3 P.M. to 6 P.M., December 10, and three hours, from 3 P.M. to 6 P.M., December 11—and the actual delivery was found to be ninety-six per cent. of the capacity as given us by Mr. Leavitt, the mechanical engineer who designed the machine. The capacity of the full pump is 194.37 gallons; the delivery per revolution, as determined by weir measurement, was 186.55 gallons; the number of revolutions made in the fifty-two hours was 57,357; and the total quantity of water delivered at the reservoir during that time, 10,700,163 gallons—or the delivery was at the rate of 205,772 gallons

per hour. The delivery required by the terms of the contract is 200,000 gallons per hour.

The duty was established as follows:—The area of the pump, by our measures of the diameter, is 534.53 square inches.

The load was determined from a gauge on the main, near the pump, the average reading of which was	64.20 lbs.
The difference of level between centre of guage and surface of water in the pump-well, reduced to pounds	8.21 lbs.
Allowance for friction and bends of main, between guage and pump-well, as at Lowell	1.00 lbs.
Total pressure per square inch	73.41 lbs.

The length of stroke, as measured, was seven feet.

From the above data, and the number of revolutions, the work done at the pump was determined, no deduction having been made for loss of action. The coal was picked Lackawanna coal, and the contractor was allowed to make use of any coal from the cinder that he deemed of value as combustible. but no credit has been allowed for screenings or unconsumed coal. The coal has been charged against the machine in gross, and the total quantity fed into the furnaces during the fifty-two hours was 15,160 pounds. The division of the foot-pounds of work by the weight of coal determined the duty, and the result is 103,923,215 foot-pounds for every one hundred pounds of coal fed into the furnaces.

The duty given by your engine is, so far as we are aware, the highest that has ever been obtained by trial test of any pumping engine in this country, and we believe that in the future it will make a good record for itself—a record that will confirm the wisdom of your action in adopting so novel a form of machine. The arrangement of parts, though unusual, appears judicious, and to have been well considered. The framing is particularly worthy of mention, as showing a distribution of material favorable for strength and rigidity.

EFFICIENCY OF FURNACES BURNING WET FUEL.

AS DETERMINED BY EXPERIMENTS ON A LARGE SCALE.

By Professor R. H. Thurston, A. M., C. E.

A Paper read before the American Society of Civil Engineers, October 21st, 1874.

(Continued from Volume lxviii, page 404.)

16. A very neat apparatus has been invented by Leicester Allen, of New York, for determining the quality of the steam furnished by a steam boiler. One of these instruments was made under the direc-

tion of the writer, for a committee of the American Institute, and used in 1872, together with the apparatus already described, at the American Institute Exhibition of that year.

17. At the trial about to be described it was impossible to condense all of the steam made, and as no "Allen Calorimeter" was obtainable, it became necessary to improvise apparatus for the occasion. The steam-pipe leading to the engine was tapped by a piece of gas-pipe, on which was fitted a stop-valve. From a short piece of pipe attached to this stop-valve a length of india-rubber hose was led to a convenient point beside the boilers, where a barrel was mounted on an accurate platform scale, 200 pounds of water were carefully weighed into this barrel, and when the scale beam precisely balanced, the weight was set ahead 10 pounds. A very accurate thermometer, which had been provided by the writer, completed this crude yet satisfactory arrangement.

At intervals during the trial the stop-valve was opened, and after allowing steam to blow through the hose freely until all water was expelled, and the hose was so thoroughly heated as to insure that no loss of heat, by the steam flowing through it, should produce condensation and render the results inaccurate, the end of the pipe was plunged into the water contained in the barrel, and the issuing steam allowed to condense until the rise of the scale beam proved 10 pounds of steam to have been added to the weight originally placed in the barrel. The temperature of the water was carefully observed at the beginning and at the end of the experiment, and the rise of temperature recorded as a basis for the estimates of priming to be given.

18. It was considered advisable to ascertain, if possible, the temperature of the products of combustion escaping to the chimney. No pyrometer was obtainable, and it became necessary to improvise another arrangement for this purpose. A mass of iron, weighing 60 pounds, was found and placed in the flue leading from the boiler, where it, after a time, attained the temperature of the gases flowing past it. A wooden vessel of convenient size and shape was obtained, and 50 pounds of water were carefully weighed into it. At intervals of two or three hours the iron was suddenly removed from the flue and dropped into this water. The initial and final temperatures were noted, and, with the range, recorded for use in calculating the temperature of the waste products of combustion. The pressure of steam was observed hourly.

19. The collated observations gave the following data:

Mean steam pressure during trial..71.4 pounds,
Total amount of spent tan burned...7.7 cords.
" " " water fed to boilers...73125 pounds.
Temperature of water entering boilers.......................................190° Fah.
" " in determining priming:

	Initial.	Final.	Range.
1st observation.............	60°	110°	50°
2d "	63°	124 (116°?)	53°(?)
3d "	62°	115°	53°

Temperature of water in determining temperature of flues:

1st observation.............	65°	119°	54°
2d "	63°	122°	59°

Weight of one cord of wet spent tan, as measured in the leach...........5447.7 pounds.
Length of trial...13 hours.

20. The determination of the total heat derived from the cord of fuel is the first and most important problem. To solve it, it is necessary to know the temperature and weight of feed water, the weight of steam produced and its temperature, the weight of water heated to the temperature of the steam, but not evaporated, and the quantity of fuel consumed. From the data obtained we can readily ascertain the total number of units of heat utilized per cord of wet fuel burned.

21. It is first necessary to calculate what portion of the 73,125 pounds of water passing through the boiler, was actually evaporated.

Each pound of steam produced, required for its generation the quantity of heat needed to raise it from the temperature of the feed-water to that due the pressure under which it was formed, and to vaporize it at that temperature.

Each pound of water, carried away in suspension by the steam, only absorbed from the fuel the amount of heat needed to raise its temperature from that of the feed-water to that of the steam.

In heating the water in the calorimeter used in testing its quality, each pound of steam gave up an amount of heat equal to that which would have been required to raised its temperature from that of the mass in the calorimeter at the end of the experiment, to that of the steam in the boiler, and to evaporate it at the latter temperature and pressure.

Each pound of water entering the calorimeter, surrendered a quantity of heat equal to that needed to raise its temperature from the final temperature of the calorimeter to that of the steam under boiler pressure.

22. The total amount of heat being the sum of these two quantities, we may construct an algebraic equation which shall embody all the conditions of our problem.*

Let H= the number of heat units per pound of steam, h= the number of heat units per pound of water, U= total heat transferred to calorimeter, W= total weight of steam and water, x= total weight of steam alone, $W-x$= weight of water alone.

$$\text{Then } Hx+h(W-x)=U;\text{ or, } x=\frac{\frac{U}{h}-W}{\frac{H}{h}-1}$$

23. At the first experiment, the steam pressure, per gauge, was 75 pounds. The temperature of steam at this pressure is 320° Fahr. The "total heat" of steam at 320°, from 0° Fahr., and at 75 pounds pressure, is (320 — 212) 0·305+212+66·6=1211·5°.

The heat transferred to the calorimeter, per pounds of steam, was therefore 1211·5 — 110=1101·5 thermal units in this experiment.

The heat transferred, per pound of water, was 320 — 110=210 thermal units.

The total quantity of heat transferred to the 200 pounds of water, by 10 pounds of mingled steam and water, was 200 (110°—60°)= 10,000 thermal units.

$$\text{Finally, } x=\frac{\frac{10000}{210}-10}{\frac{1101{\cdot}5}{210}-1}=8{\cdot}87\text{ pounds steam.}$$

$$W-x=10-8{\cdot}87=1{\cdot}13\text{ pounds of water.}$$

The percentage of priming was, therefore, 11·3. The ratio of weight of steam and water was $\frac{8{\cdot}87}{1{\cdot}13}=7{\cdot}85$, the water being $\frac{1{\cdot}13}{8{\cdot}87}\times100=12{\cdot}74$ per cent. of the steam.

24. The other experiments were made with the steam pressure as before, and, in the second, the valve of $W-x$ comes out negative, indicating superheating. This may, possibly, have actually occurred as a consequence of the water having fallen slightly below the upper row

*See Report of Committee on Test of Steam Boilers; Trans. Am. Inst., 1871-2.

of tubes in one boiler, but it is more probable that the reading, 124°, does not represent the mean temperature of the mass of water in the calorimeter. In this experiment, the water was not as carefully stirred with the thermometer as in the other experiments, and the temperature was taken at the surface of the water, after a first and otherwise satisfactory reading of 116° had been obtained, but a second application of the steam jet had been necessary, to accurately balance the scale, which heated the surface above the average temperature of the mass previously heated. The true reading can probably have been no higher than 116° or 117°, and it is taken for purposes of calculation at the former figure, although the lowest unrecorded reading, finally, actually obtained at the middle of the well stirred mass was 116°.

$$\text{Then } x = \frac{\frac{10600}{204} - 10}{\frac{1095{\cdot}5}{204} - 1} = 9.6 \text{ pounds steam,}$$

and the weight of water being $10 - 9{\cdot}6 = 0{\cdot}4$, the percentage of priming was 4, and the water carried over weighed $\frac{0{\cdot}4}{9{\cdot}6} \times 100 = 4{\cdot}3$ per cent. as much as the steam with which it was mingled.

In the third experiment

$$x = \frac{\frac{10600}{205} - 10}{\frac{1096{\cdot}5}{205} - 1} = 9{\cdot}59\,;\ W - x = 0{\cdot}41.$$

The percentage of priming was 4·1, and of water to steam 4·2 per cent.

The mean percentage of priming was 6·47. The mean percentage of steam alone was 93·53.

25. The total quantity of heat derived from the fuel and taken up by the boilers can now be divided into two portions and each calculated.

The total weight of steam produced was $73125 \times {\cdot}9353 = 68393{\cdot}8$.
" " water primed " $73125 \times {\cdot}0647 = 4731{\cdot}2$.

The mean pressure at which this steam was formed being 71·4 pounds, we find its "total heat" per pound to be 1210·6 thermal

units, and the heat communicated to each pound of feed entering at 190°, and evaporated at this pressure, 1020·6 units. The average heat received from the fuel by each pound of water not evaporated was 127 thermal units.

Then $68393{\cdot}8 \times 1020{\cdot}6 = 69802712{\cdot}3$ units,

and $4731{\cdot}2 \times 127{\cdot}0 = 600862{\cdot}4$ "

Total heat from the fuel $= 70403574{\cdot}7$ thermal units.

$$\text{Total heat per cord of tan} = \frac{70403574{\cdot}7}{7{\cdot}7} = 9143321{\cdot}4 \text{ units.}$$

26. the usual standard, as generally accepted by Engineers in examples of this kind, is the evaporation of one pound of water, at the boiling point, and under atmospheric pressure.

The heat required is the latent heat at 212°, or 966·6 thermal units per pound. We have therefore—

Equivalent evaporation, by one cord of wet spent tan, from 212°, under atmospheric pressure:

$$\frac{9143321{\cdot}4}{966{\cdot}6} = 9459{\cdot}2 \text{ pounds of water.}$$

27. Under these conditions, 10 pounds of water would be considered a fair evaporation per pound of good coal, and in this example, therefore, the furnace utilized from each cord of tan the equivalent of 946 pounds of coal.

28. A quantity of the tan was placed in a "fruit jar," and hermetically sealed. This tan was carefully weighed by Professor Geyer, at the Stevens Institute of Technology, was dried by exposure to the air in the study of the writer for one week, and then was again weighed by Prof. Geyer, in the presence of the writer. The weights, before and after drying, were respectively 656·8 grammes, and 268·8 grammes. This fuel contained, therefore, 59 per cent. water, and but 41 per cent. woody fibre.

The weight of a cord of this tan, measured in the leach, and then well dried in the open air, would be 2233·56 pounds, and the equivalent evaporation per pound becomes 4·24 plus that of the water contained in the fuel, say 1·44, or 5·68 pounds water per pound of combustible.

29. The determination of the temperature of chimney flue, or of the escaping gaseous products of combustion, is thus made. At the

first observation, 50 pounds of water were heated from 65° to 119° Fahr., a range of 54°, by the cooling of a mass of iron weighing 60 pounds, from an unknown temperature to 119° Fahr. The amount of heat communicated to the water was $50 \times 54 = 2700$ thermal units. Each pound of iron, therefore, parted with $\frac{2700}{60} = 45$ units of heat.

The specific heat of iron is given by Watts as 0.112. It requires, therefore, the cooling of one pound of iron through nine degrees of temperature to heat a pound of water one degree. The iron, in the case considered, must therefore have lost $45 \times 9 = 405°$ Fahr., when cooled to 119°, and its original temperature, and that of the escaping gases in the flue, must have been $405° + 119 = 524°$ Fahr.

The second observation in a similar manner, gives the temperature of the chimney flue at 564°·5 Fahr.

Watts gives 315° centigrade, 599° Fahr., as a proper temperature with natural draft.

Rankine gives absolute temperature of external air multiplied by $\frac{25}{12}$ as the temperature giving most effective draught. In this case, therefore, in which the average temperature of the air was 74°, the best temperature of chimney would have been $\left(25\frac{74+461}{12}\right) - 461 = 645°$ Fahr.

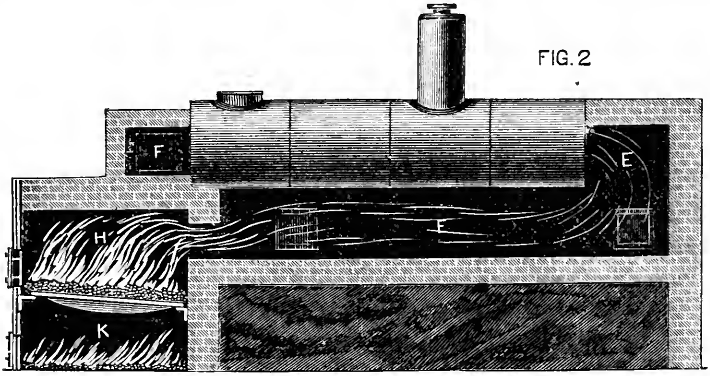
30. The minute inaccuracy of the results thus obtained, which is due to changes of the specific heat of water, and of metal, under varying temperatures, is of no practical importance. As the vessel containing the water heated was of wood, in each case, the usual correction for heating the vessel when metallic becomes of no importance also, and the weight of the thermometer being insignificant in comparison with that of the water, that correction is unnecessary. This method is of great value as a last resort, in absence of other good heat measuring appliances.

THE CROCKETT FURNACE.

31. The second furnace which was experimented upon by the writer, was of the form known as the "Crockett." This form of furnace is shown in Fig. 2, and that here described was of the same

general form as that illustrated, differing principally in its arrangement of bridge walls.

FIG. 2



In this example two furnaces were constructed side by side, each having a grate surface of 4 × 6 feet, the total grate area of both being 48 square feet.

The grates were of cast iron, of ordinary form, set so closely that none of the wet fuel could fall through into the ash-pit. It was stated that it was not intended that the charred fuel should fall through and burn in the ash-pit.

During this trial, however, more or less burning tan was continually falling into the ash-pit and burning there. This, undoubtedly, assisted, in some degree, in the desiccation of the wet fuel, by direct radiation of heat, and by heating the entering air as it passed over this bed of hot coals. To this extent the furnace resembled, in its action, the Thompson furnace, already described.

Above the grates a brick arch was turned, as shown, against which the products of combustion impinged and the heat radiated from the burning fuel on the grate, keeping this arch at a high temperature, it assisted the process of desiccation of wet fuel, when first thrown in, by strongly radiating upon it the heat thus stored up while the fires were most intense. From the furnace the gases passed directly into the flues beneath the boiler.

32. The tan, wet from the leach, was charged into the furnaces through the doors in the front, as in all usual forms of furnace, and the process of "firing" differed but little from that usual with thin fires, where coal is used. The fuel was thrown in at intervals of between 5 and 8 minutes, the furnace-man taking care, first, to fill all

holes in the burning mass, and, next, covering the whole with a very evenly distributed and very thin layer of fresh fuel. This fresh charge was quickly dried by the heat of the burning fuel, over which it was spread, and by the heat radiated from the hot furnace arch above it, and, taking fire, burned freely. No special effort seemed to be made to obtain "alternation" in working the furnace, but the irregularity with which the fuel burned at different parts of the grate did, perhaps, secure something of this effect.

33. The fuel was measured in the leach, as in the previous case, and about a half leach, measuring $4\frac{1}{2}$ cords, was burned during the trial, between 8 o'clock A. M. and 6 o'clock P. M. The actual working time was 9 hours, the work being stopped from 12 M. to 1 P. M.

34. The tan bark burned was hemlock, mixed with some oak. It looked like a better material than that used in the other trial. It was more cleanly ground, seemed less "soggy," and had a much better color.

35. The boilers used here were two in number. One was an old-fashioned "Cornish" boiler, 4 feet in diameter and 18 feet long, with one 24-inch flue. The second was 6 feet in diameter, with four 18-inch flues; the total length was 15 feet. The gases from the furnace were led under the boilers, and then, with a double return through the boiler-flues to the chimney. The total heating surface, reckoned as before, was very closely 700 square feet.

36. The flues were stated to have been so long in use without cleaning, that the draught was somewhat impeded by the accumulation of ashes beneath the boilers, and that the rapidity of combustion was somewhat lessened. The two trials are, therefore, both to be taken as representing less than the maximum capacity of the furnaces.

37. The trial was made by a somewhat similar method to that adopted in the one already described. The quality of steam was determined similarly. The water was measured differently. In this case the capacity of the feed-pump exceeded several times the requirements of the boiler, and the only absolutely reliable means of determining the quantity of fuel seemed to be to measure every pound going to the pump, thus evading the uncertainty attending any attempt to secure regularity in the action of the latter.

38. A barrel was fitted to the suction-pipe of the pump, and an employé of the Mechanical Laboratory of the Stevens Institute of Technology was stationed with a hose to fill it with water, when it

became empty, and to keep an account of the number of barrels used, while an employé of the proprietors of the tannery, stationed at the pump, checked the account. All of the water fe l into the boilers during the trial was thus measured, and at the close of the trial the barrel was taken out, filled on the scales, and the weight of its contents determined.

39. There was no opening into the chimney flue through which the escaping gases could be reached, and their temperature was not determined.

40. The amount of smoke issuing from the chimney of this furnace was considerably greater than was observed at the preceding trial, indicating that the Thompson Furnace secured a somewhat more perfect combustion than the Crockett.

41. The results of this trial gave the following data:

Total number of cords of tan burned, . . . 4·5
" weight of water fed to boilers, . . . 28 509 pounds.
Temperature of feed-water entering boilers (estimated), 160° Fahr.
" water observed in determining "priming":

	Initial.	Final.	Range.
1st observation, . . .	68°	118°	50°
2d " . . .	70°	118°	48°
3d " . . .	76°	126°	50°
4th " . . .	76°	124°	48°

Length of trial, ... 9 hours.

42. Estimating the priming as before, we obtain from the several observations, which were made with the steam pressure, per gauge, 55, 50, 45 and 60 pounds, respectively, $x = 9·02$, $x = 8·07$, $x = 9·12$, and $x = 8·55$, and the percentage of priming, 9·8, 19·3, 8·8, 14·5 per cent. The mean of all observations gives the average percentage of priming at 13·1 per cent., and indicates that the steam issuing from the boiler carried in suspension 15 per cent. of its own weight of unevaporated water.

43. We determine the total heat from the fuel thus:

Steam produced, . . . $28\,509 \times 0·869 = 24\,774·32$ pounds.
Water primed, . . . $28\,509 \times 0·131 = 3\,734·68$ "

The mean pressure of steam during the trial was 50·44 pounds per square inch, and its temperature 298° Fahr. Its total heat at 298° from 0° was 1204·8 units per pound. Then we have

Total heat, per pound of steam	1204·8 — 160 = 1044·8
" " water	298 — 160 = 138, and
Total heat transferred from fuel to steam	25 884 209·54 units.
" " " water	515 385·84 " and hence
Total heat transferred from fuel to feed	26 399 595·38 units.
" per cord of wet tan	6 866 576·75 "
Equivalent evaporation per cord, water at 212°	7 103·84 pounds.
" weight of coal per cord of tan	710·38 "

44. A sample of the fuel used in this trial was sealed up, as before, and was similarly weighed at the Stevens Institute of Technology, dried in the air one week, and its loss of moisture determined.

This sample contained 55 per cent. of water, and 45 per cent. ligneous material. The weight of the tan in the leach was judged to be practically the same as in the preceding trial, and the equivalent evaporation per pound is $\frac{7103 \cdot 84}{2233 \cdot 56} = 3 \cdot 19$ plus the water held by the fuel, say 1·22, or 4·41 pounds.

(To be Continued.)

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxviii, page 425.]

DESIGNING MACHINES.

It will hardly be expected that any part of these articles that are intended mainly for apprentices, should relate to designing machines, yet there is no reason why the subject should not to some extent be studied from the beginning of a course.

There is, perhaps, no one who has achieved a successful experience as an engineer but will acknowledge the advantages derived from early efforts to generate original designs, and at the same time, admit that if these first efforts had been properly directed, the advantages gained would have been greater still.

There is nothing more difficult, in the absence of experimental knowledge, than for an apprentice engineer to discriminate and choose plans for his own education, or to determine the best way of pursuing such plans when they have been chosen; and there is nothing that consumes so much time or is more useless than making original plans, if there is not some systematic method followed in such attempts.

There is no object in preparing designs, when their counterpart may already exist, so that in making original plans, there should be some knowledge of what has been already done in the same line; it is not only discouraging, but annoying, after studying a design with great care, to find that it has been anticipated, and that the work has been one of reproduction only; for this reason, attempts to design should at first be confined to familiar subjects, instead of venturing upon unexplored ground.

Designing is in many respects the same thing as invention, except that it deals more with mechanism than principles, although it may, and often does include both. Like invention, designing should always be attempted for the attainment of some definite object laid down at the beginning, and followed persistently throughout; without such an object the time spent in designing is apt to be lost.

It is not always an easy matter to hit upon an object to which designs may be directed; and although at first thought it may seem that any machine or part of a machine is capable of improvement, it is no easy matter to define existing faults nor to conceive of plans for their remedy.

A new design should be predicated upon one of two suppositions, either that existing mechanism of the same kind is imperfect in its construction, or that it lacks functions that the new design may supply, and if those who spend their time in making plans for novel machinery would stop to consider this fact before beginning, it would save no little time that is wasted in what is termed scheming without a purpose.

Aside from determining the precise object of an improvement, and arriving at the principles of operating in the preparation of designs, there is nothing connected with constructive engineering that can be more nearly brought within general rules and principles than that of detailing machines. I am well aware of how far this statement is at variance with popular opinion among mechanics on this subject, and

also of the very thorough knowledge of machine application and machine operation that is required in making designs, and mean, that when the premises are once laid down, there are certain principles and rules that may determine their arrangement and distribution of material, the position and relation of moving parts, so that a machine may be built up without any more risk of mistake than in building a house.

Designing machines includes their adaptation, endurance and cost. Adaptation referring to the performance of machinery, its commercial value, or what the machinery may earn in operating, as compared to hand labor. Endurance, to the time that machines may operate without detention for repairs, and the constancy of their performance; and cost, to the investment represented in the machinery, which must be in proportion to the nature and amount of the work performed.

The adaptation, endurance, and cost of machines, may be resolved into movements, arrangement of parts, and proportions. Movements and strains may be called the base upon which designs for machines are based; movements determining the general dimensions, and strains the proportions and sizes of particular parts. Movement and strain determine the nature and area of bearings and bearing surfaces.

The range and speed of movements in machines are elements in designing that admit of a definite determination from the condition of their operation, but arrangement cannot be so determined and is the most difficult point to find data for in preparing original designs. To generalize, there must be, in designing:

First, a conception of certain functions or an object which the mechanism is to accomplish.

Second, plans of adaptation and arrangement of the component parts of the machinery, or organization as it may be called.

Third, a knowledge of specific conditions, such as strains and the range and rate of movements.

Fourth, there must be proportions of the various parts, including bearings and bearing surfaces.

To illustrate the practical application of these propositions, let it be supposed, for example, that a machine is to be made for cutting the teeth in gear racks, of three-fourths inch pitch and three inches face, and that we are to set out to prepare a design from original premises and without any reference to such machines as may be in use for this purpose.

It is not proposed that an actual design shall be made that will by words alone convey a comprehensive idea of an organized machine, but to proceed by a course that will illustrate the plan of reasoning that is most likely to attain a successful result.

The reader, in order to understand what is said, may keep in his mind a shaping machine with crank motion, a machine that very nearly fills the segments of cutting tooth racks.

Having assumed a certain work to do, the cutting of tooth racks three-fourths inch pitch and three inches face, the first thing to be considered will be, is the machine to be a special one, or one of general adaptation? This question has to do, first, with the functions of the machine in the way of adapting it to the cutting of racks of other sizes, or other kinds of work, and secondly, as to the completeness of the machine, for if it is to be a standard one, instead of being adapted only to a special use, there is in the first case many expensive additions that may be made which can be omitted in a special machine. It will, therefore, be assumed in this example that a special machine is to be constructed to perform a particular duty only.

The nature of the work to be performed consists in cutting away the metal between the teeth of the rack, leaving a perfect outline for the teeth, and as this shape of the teeth cannot well be obtained by adjustment of the tools, it must be attained by the shape of the tools. As the shape of the tools must be maintained, and the cross section of the displaced metal is not too great, we at once conclude that the shape of the tools should be a profile of the space between the teeth, and the whole cut away at one setting or one operation. By the application of principles laid down in a former place in reference to cutting various kinds of material, it is decided to use reciprocating or planing tools, instead of rotary or milling tools to cut away the metal in the present case.

Next, we come to movements which consist in a reciprocating cutting movement, a feed movement to graduate the cutting, and a longitudinal movement of the rack with means to graduate the pitch of the teeth.

The reciprocating cutting movement being but four inches or less, a crank is obviously the best means to produce this motion, and as the movement is transverse to the rack which may be long and unwieldy, it is equally obvious that the cutting motion should be given to the tools instead of the rack.

The feed adjustment of the tool being intermittent and the amount of cutting edge that acts continually varying, this movement should be performed by hand so as to be controlled at will by the sense of feeling. The same rule applies to the adjustment of the rack for spacing, which being intermittent and irregular as to time, should be performed by hand. The speed of the cutting movement from established data we know should not exceed from sixteen feet to twenty feet a minute, and that a belt two and one-half inches wide must move two hundred feet a minute to propel an ordinary metal cutting tool, so that the crank movement must be increased by gearing until this speed of the belt is reached. This will furnish the general speed of pulleys and gear wheels.

Next comes arrangement; in this the first matter to be considered is the convenience of manipulation. The cutting should be within easy view, so as to be watched, and horizontally, to be more easily watched. The operator has to keep his hand on the adjusting or feed mechanism, which is about twelve inches above the work, and it follows that if the cutting level is four feet from the floor, and the feed handle five feet from the floor, the arrangement will be convenient for a standing position. It may also be assumed that as the work requires continual inspection and hand adjustments, it would be a proper arrangement to overhang both the supports for the rack and the cutting tools, placing them, as we may say, outside the machine, to secure convenience of access and allow inspection. The position of the cutting bar, crank, connections, gearing, pulleys and shafts, will assume their respective places from the obvious conditions arising from the position of the operator and the work.

Next in order are strains; as the cutting is the source of the strains, and as the resistance offered by the cutting tools is as the length of the acting edge, we find in this case that while all other conditions have pointed to a small machine we have here a new one that calls for large proportions. In displacing the metal between the teeth of three-fourths inch pitch, the cutting edge or the amount of surface acted upon is equal to a width of one and one-half inches; it is true, the displacement may be but small at each cut, but the strain, as remarked before, is rather to be predicated upon the breadth of the acting edge, and we find here conditions that create strains equal to the average duty of a large planing machine. This strain radiates from the cutting point as from a centre, falls on the supports of the

work with a tendency to force it from the framing, acts between the rack and the crank shaft bearing, through the medium of the tool, cutter bar, connection, and crank pin, and in various directions and degrees that may be very well defined in making a drawing. Besides this cutting strain, there are none of importance. The tension of the belt, the side thrust in bearings, the strain from the angular thrust of the crank, and the end thrust of the tool, are all insignificant, and while not to be lost sight of, need not to have much to do in questions of proportion or special arrangement.

In the strains we find data for special arrangement, which is quite a distinct matter from general arrangement, the latter being governed by the conveniences of manipulation. Special arrangement deals with and determines the shape of framing, following the strains throughout the machine. In the present case we have a cutting strain which will be assumed as equal to one ton exerted between the bracket or jaws that support the work and the crank shaft. It follows that between these points the metal in the framing should be disposed in as direct a line as possible, but as the frame cannot follow this line but must go below it, provision must be made to resist flexion by a deep section vertically, and parallel with the cutting motion.

Lastly, proportions; having estimated the cutting force required at one ton, which will serve for illustration, although less than the actual strain in a machine of this class, we proceed upon this to base proportions, beginning with the tool shank, and following back through the adjusting saddle, the cutting bar, connections, crank pins, shafts, and gear wheels to the belt. Starting again at the tool, or point of cutting, following back through the supports of the rack, the jaws that clamp it, the saddle for the graduating adjustment, the connections with the main frame, and so on to the crank shaft bearing, giving dimensions to each piece that is sufficient to withstand the strains without deflection or danger of breaking. These proportions cannot, I am aware, be brought within the rules of ordinary practice by relying upon calculation alone to fix them, and no such a course is suggested; calculation may aid, but cannot determine proportions in such cases; besides, symmetry, which cannot be altogether disregarded, often modifies the form of cast iron framing.

I have in this way indicated a methodical plan of proceeding to generate a design, as far as words alone will serve, beginning with certain premises to define the purpose to be attained, and then pro-

ceeding to consider in consecutive order the general character of the machine, mode of operation, movements and adjustments, general arrangement, strains, special arrangement, and proportions.

With a thorough practical knowledge of machine operation and an acquaintance with existing practice, an engineer proceeding upon this plan will, if he does not overlook some of the conditions, generate machine designs that will remain without much modification or change so long as their purpose, to which it is directed, remains the same.

Perseverance is an important trait to be cultivated in first efforts to generate designs; it takes a certain amount of study to understand any branch of mechanism, no matter what natural capacity may be brought to bear. Mechanical operations are not learned intuitively, and are always surrounded by many peculiar conditions that must be learned seriatim, as we may say, so that it is only by an untiring perseverance at one thing that there can be any hope of improving it by new designs.

The learner who goes from gearing and shafts to steam and hydraulics, from machine tools to cranes and hoisters, will not accomplish much. It is a good plan to select an easy subject at first, one that admits of a great range of modification, and if possible, one that has not assumed a standard form of construction. Bearings and supports for shafts and spindles, is perhaps one of the best.

In bearings for shafts the strains are easily defined, while the pivotal support, vertical and lateral adjustment, and lubrication of bearings and symmetry of supports and hangers will furnish material for endless modification, both as to arrangement and mechanism.

In making designs never use any references except what is carried in the mind. The more familiar a person is with machinery of any class, the more able he may be to prepare designs, but not by measuring and referring to other people's plans. Dimensions and arrangement are in this way carried into a new drawing, even by the most skilled, without their being at the time conscious of it; besides, it is by no means a dignified matter to collect other people's plans and by combination and modification to produce new designs. This may be, at first, an easy plan to acquire a certain kind of proficiency, but will most certainly hinder an engineer from ever rising to the dignity of an original designer. The custom of using references destroys confidence and inculcates habits of thought and a want of originality that when once acquired are not easily got rid of.

Symmetry, as an element in designs for machinery, is one of those unsettled matters that can only be determined in connection with particular cases. I may, however say, that in all engineering implements and manufacturing machinery of every kind, there should be nothing added for ornament, or that has no correlation with the functions of the machinery.

Modern engineers of the better class are so thoroughly in accord in this matter in both opinion and practice, that it hardly requires to be mentioned; but it will be no disadvantage to the learner who intends to devote his time to mechanics to commence by cultivating a contempt for whatever has no useful purpose. Of existing practice it may be said, that in what may be called industrial machinery, the amount of ornamentation met with is inversely as the amount of engineering skill that was employed in preparing the designs.

Perhaps a safe rule will be to assume that all machinery that is used and seen by the skilled, should be devoid of ornament, and that machinery that is publicly seen by the unskilled, should have some ornament in its composition. If there is to be any rule, this would seem to be a proper one, and accords with modern practice, for, by common consent, steam fire engines, water works engines, sewing machines, and other work of this class that falls mainly under the inspection of the unskilled, is usually arranged with more or less ornamentation.

Ornament, when attempted, should never be carried further than graceful proportions, and the arrangement of framing should follow as nearly as possible the lines of strain. Extraneous ornamentation, such as detached filagree work of iron, or painting in colors, is so repulsive to the taste of the true engineer and mechanic that there is but little use in arguing against it.

INVENTION.

The relation between invention and the engineering arts, and especially between invention and machines, will warrant a short review of the matter here; or even if this reason was wanting, there is a sufficient one in the fact that one of the first aims of an engineering apprentice is to "invent" something, and as the purpose is, so far as possible, to say something upon each subject in which the beginner has an interest, invention must not be passed over. It has been the object, this far, to show that machines, processes, and mechanical manipulation generally may be systematized and generalized to a

greater or less extent, and that a failure to reduce mechanical manipulation and machine construction to certain rules and principles can only be ascribed to a want of knowledge, and not to any inherent condition or principle that prevents such a solution. This same proposition is applicable to invention, with the difference that invention, in its true sense, may admit of a more perfect generalization than even machines and processes.

By the term invention, as applied to mechanical improvements, is not meant chance discovery, a construction that is commonly placed upon the term, but deductions wrought out from certain principles or premises that have been proved and acknowledged; the results attained by the application of intelligent research and experiment, as distinguished from what may be called discovery; in short, demonstration, which may be applied to any improvement that is not the result of chance.

In the sciences that rest in any degree upon physical experiment, like chemistry, discovery and experiments without a definite purpose, may be a proper kind of research, and may, in the future, as it has in the past, lead to great and useful results; but in mechanics the matter is different; the demonstration of the conservation of force, and the relations between force and heat, has supplied the last link in a chain of principles that may be said to comprehend all that we are called upon to deal with in ordinary mechanics, and there remains but little hope of developing anything new or useful by discovery alone. The time has been, and has not yet passed away, when even the most unskilled thought their chances of inventing improvements in machinery were almost equal with that of the engineer and skilled mechanic, but this has been changed in late years, and new schemes are now weighed and tested by scientific analysis, that is often more reliable than actual experiments, unless the experiments are scientifically performed. The veil of mystery that an ignorance of the physical sciences had thrown around mechanics has been cleared away, and so far has mechanical superstition, if the term may be allowed, and chance discovery disappeared, that many of our best modern engineers regard their improvements in machinery but the exercise of their profession, and hesitate about asking for protective grants that will secure an exclusive use of that which another might and often does demonstrate whenever circumstances called for such improvement. There are, beyond doubt, new articles of manufacture to be discovered, and perhaps improvements in machinery that will be

proper subject matter for patents; improvements that in all chance would not be made for the term of a patent except by the inventor; but such cases are very rare, and it is fair to assume that unless an invention is one that could not be regularly deduced from existing data, and one that would not, in all probability, have been made for a long term of years by any other person than the inventor, then the inventor can have no natural right to exclusive use that will not infringe that of others.

It is not, however, the intention to discuss patent law now, even to judge what benefits have in the past, or may in the future be gained to technical industry by the patent system, but what I do wish to do is to impress the engineering apprentice with a better and more dignified appreciation of his calling than to confound it with chance invention, and thereby destroy that confidence in positive results which characterizes modern mechanical engineering. I would also have him guard against the loss of time and effort that is often expended in searching after inventions for the object of gain, reminding him that such schemes are always predicated upon an assumed ignorance on the part of others that often turns out a mistake.

Let the apprentice invent or demonstrate all that he can, the more the better, but let it be according to some system, and with a proper object. Never spend time in groping in the dark after an object of which no definite conception has been formed, nor after any project that is not to fill an ascertained want; that is, never make an invention and then have to hunt up a use for it, but start methodically, as a bricklayer builds a wall, as he mortars and sets each brick as he goes along, so qualify each piece or movement that is added to the mechanical structure, so that when done, the result may be useful and enduring.

As remarked, every attempt to generate anything new in machinery should be commenced by ascertaining a want for the improvement; first find a fault in what exists, or is already known, and set out with a definite object in view. Study the general principles upon which this fault is to be remedied, or upon which the want may be met, and then "fill in" the mechanism like the missing link in a chain. These propositions, stated in this way, will no doubt fail to convey the full meaning intended, and I will assume an example to render this systematic plan of inventing more plain, choosing the valve movement of steam hammers as a new subject.

Presuming that the apprentice has read what was said of steam hammers in another place, or is from other sources already familiar with the uses and general construction of hammers, let us suppose that steam hammers, with the ordinary automatic valve action, to be well known and understood, so far as those that give an elastic or steam-cushioned blow. Next, suppose that by analyzing the nature of the blow given by hammers of this class, either by mathematical deductions, theoretical inference, or by experiment, it has been demonstrated that dead blows, where the hammer comes to a full stop in striking work, to be more effectual in certain kinds of work, and that steam hammers would be improved by being arranged to operate upon this principle. This would constitute the first stage of the invention, by demonstrating a fault in existing hammers, and a want of certain functions that would, if added, improve them.

Proceeding from these premises, the first thing should be to examine the principles and plans of existing valve gear, to see where this want of functions lies, and to gain the aid of suggestions that the existing mechanism may offer, also to see how far the appliances in use may become a part of any new system that is to be applied.

By examining the rebounding hammers it will be found that the valve is connected to the drop by means of links, that produce a coincident movement of the piston and valve, and that the movement of one is contingent upon and governed by the other. It will be seen that these connections or links are capable of extension in their length, to alter the relative position of the piston and valve, thereby regulating the range of the blow, but still the movement of the two is reciprocal or in unison. Reasoning inductively, not discovering or inventing, it may be determined that to secure a stamp or dead blow of the hammer head, the valve must not open or admit steam beneath the piston until the blow is completed and the hammer has stopped. Here occurs one of those mechanical problems that especially require logical solution. The valve must be moved by the drop, there is no other moving mechanism to give motion to it; besides, the valve and drop must be connected, to insure coincident action, but the valve requires to move when the drop is still. Proceeding still inductively, it is clear that a third agent must be introduced, some part that is moved by the drop, and in turn moves the valve, but so arranged that this intermediate agent may *continue to move after the hammer-drop has stopped.*

(To be continued.)

Chemistry, Physics, Technology, etc.

ON THE EFFECT OF ACID ON THE INTERIOR OF IRON WIRE.*

By Professor Osborne Reynolds, M. A.

It will be remembered that at a previous meeting of this society, Mr. Johnson exhibited some iron and steel wire in which he had observed some very singular effects produced by the action of sulphuric acid. In the first place the nature of the wire was changed in a marked manner, for although it was soft charcoal wire it had become short and brittle; the weight of the wire was increased; and what was the most remarkable effect of all was that when the wire was broken, and the face of the fracture wetted with the mouth, it frothed up as if the water acted as a powerful acid. These effects, however, all passed off if the wire were allowed to remain exposed to the air for some days, and if it were warmed before the fire, they passed off in a few hours.

By Mr. Johnson's permission, I took possession of one of these pieces of wire and subjected it to a farther examination, and from the result of that examination I was led to what appears to me to be a complete explanation of the phenomena. I observed that when I broke a short piece from the end of the wire the two faces of the fracture behaved very differently—that on the long piece frothed when wetted and continued to do so for some seconds, while that on the short piece would hardly show any signs of froth at all. This seemed to imply that the gas which caused the froth came from a considerable depth below the surface of the wire, and was not generated on the freshly exposed face. This view was confirmed when on substituting oil for water I found the froth just the same. These observations led me to conclude that the effect was due to hydrogen, and not to acid, as Mr. Johnson appeared to think, having entered into combination with the iron during its immersion in the acid, which hydrogen gradually passed off when the iron was exposed. It

* A paper read before the Manchester Literary and Philosophical Society. Reprinted from the London *Engineer*.

was obvious, however, that this conclusion was capable of being further tested. It was clearly possible to ascertain whether or not the gas was hydrogen, and whether hydrogen penetrated iron when under the action of acid. With a view to do this I made the following experiments.

First, however, I would mention that after twenty-four hours I examined what remained of the wire, when I found that all appearance of frothing had vanished and the wire had recovered its ductility, so much so that it would now bend backwards and forwards two or three times without breaking, whereas on the previous evening a single bend had sufficed to break it. I then obtained a piece of wrought iron gas pipe, 6 inches long and $\frac{5}{8}$ inch external diameter, and rather more than 1-16 inch thick; I had this cleaned in a lathe both inside and outside; over one end I soldered a piece of copper so as to stop it, and the other I connected with a piece of glass tube by means of india-rubber tubes. I then filled both the glass and iron tubes with olive oil and immersed the iron tube in diluted sulphuric acid which had been mixed for some time and was cold. Under this arrangement any hydrogen which came from the inside of the glass tube must have passed through the iron. After the iron had been in acid about five minutes small bubbles began to pass up the glass tube. These were caught at the top and were subsequently burnt and proved to be hydrogen. At first, however, they came off but very slowly, and it was several hours before I had collected enough to burn. With a view to increase the speed I changed the acid several times without much effect until I happened to use some acid which had only just been diluted and was warm; then the gas came off twenty or thirty times as fast as it had previously done. I then put a lamp under the bath and measured the rate at which the gas came off, and I found that when the acid was on the point of boiling as much hydrogen was given off in five seconds as had previously come off in ten minutes, and the rate was maintained in both cases for several hours. After having been in acid some time the tube was taken out, well washed with cold water and soap so as to remove all trace of the acid; it was then plunged into a bath of hot water, upon which gas came off so rapidly from both the outside and inside of the tube as to give the appearance of the action of strong acid. This action lasted for some time, but gradually diminished. It could be stopped at any time by the substitution of cold water in place of the hot, and it was renewed

again after several hours by again putting the tube in hot water. The volume of hydrogen which was thus given off by the tube after it had been taken out of hot acid was about equal to the volume of the iron. At the time I made these experiments I was not aware that there had been any previous experiments on the subject; but I subsequently found, on referring to Watts' "Dictionary of Chemistry," that Cailletet had in 1868 discovered that hydrogen would pass into an iron vessel immersed in sulphuric acid. See *Comp. Rend.* lxvi., 847. The facts thus established appear to afford a complete explanation of the effects observed by Mr. Johnson.

In the first place, with regard to the temporary character of the effect, it appears that the hydrogen leaves the iron slowly even at ordinary temperatures—so much so that after two or three days' exposure I found no hydrogen given off when the tube was immersed in hot water. With regard to the effect of warming the wire—at the temperature of boiling the hydrogen passed off 120 times as fast as at the temperature of 60 deg. Also when the saturated iron was plunged into warm water the gas passed off as if the iron had been plunged into strong acid; so that we can easily understand how the hydrogen would pass off from the wire quickly when warm, although it would take long to do so at the ordinary temperatures. With regard to the frothing of the wire when broken and wetted, this was not due, as at first sight it appeared to be, simply to the exposure of the interior of the wire, but was due to warmth caused in the wire by the act of breaking. This was proved by the fact that the froth appeared on the sides of the wire in the immediate neighborhood of the fracture, when these were wetted, as well as the end; and by simply bending the wire it could be made to froth at the point where it was bent. As to the effect on the nature and strength of the iron, I cannot add anything to what Mr. Johnson has already observed. The question, however, appears to be one of very considerable importance, both philosophically and in connection with the use of iron in the construction of ships and boilers. If, as is probable, the saturation of iron with hydrogen takes place whenever oxidation goes on in water, then the iron of boilers and ships may at times be changed in character and rendered brittle in the same manner as Mr. Johnson's wire, and this, whether it can be prevented or not, is at least an important point to know, and would repay a further investigation of the subject.

// JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXIX. FEBRUARY, 1875. No. 2.

EDITORIAL.

Franklin Institute.

HALL OF THE INSTITUTE, Jan. 20th, 1875.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

The minutes of the last stated meeting, as likewise those of the special meeting held Wednesday, December 23d, 1874, were read and approved.

The Secretary then read the following

REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, FOR THE PROMOTION OF THE MECHANIC ARTS, FOR THE YEAR 1874.

Your Board report that during the year just passed 453 names have been added to the list of members, while but 11 resignations have been accepted, making an addition of four hundred and forty-two (442). an increase of 382 greater than during the year 1873. Of these nine (9) have purchased first-class stock, fifty-six (56) have purchased second-class stock, and six have become life members. This increase was due mainly to the recent exhibition, and partly to

exertions made by your Board to induce others than residents of Philadelphia to become members of our old and useful Institute. For the first time in many years a balance of any considerable amount stands to the credit of the Institute. The Treasurer's report tells us that the

Balance on hand Jan. 1st, 1874, was	$1,696·52
Receipts during the year, . .	112,408·59
Total, . . .	$114,105·11
Payments during the year, . .	52,769·02
Leaving a balance on hand of .	$61,336·09

The Treasurer has furnished your Board with a statement of the indebtedness of the Institute, which amounts to about $21,837·07. The means to meet said indebtedness, January 1st, 1875, were as follows:

U. S. 6 per cent. Loan, . .	$6,000·00
Cash on Hand, . . .	61,336·09
	$67,336·09

The above means do not include the value of the Hall, Library, and collection of the Institute.

The Committee on Publication make the gratifying statement that the Journal of the Institute has this year cleared its expenses, although in such expenses have been estimated the salary of the editor for part of the year.

Additions have been made to the library of

Bound Volumes, ...	77
Unbound, including Journals, Pamphlets, Proceedings of Societies, etc., . .	123
British Patent Specifications, estimated, .	100
Total, ...	300

The drawing school, during the spring term, was under the charge of Prof. Alfred C. Wernicke, and was attended by seventy-six pupils. During the summer it was found that the services of Prof. L. M. Haupt could be secured, and the drawing school arranged in classes under competent assistants. This plan has proved very advantageous,

and the attendance during the fall term was increased to one hundred and thirty-two (132) pupils.

In last year's report allusion was made to gentlemen who volunteered as lecturers, *i. e.*, who gave their services for the good of the Institute, and their names were mentioned in the yearly report. The list in the fall course was headed by Prof. Robert E. Rogers, M. D., as a volunteer, and during the term of 1874-75. Dr. Henry Leffman, Mr. S. Lloyd Wiegand, Mr. J. B. Knight, and Mr. Robert Grimshaw also are in the list of volunteers. Valuable lectures were delivered by Prof. E. J. Houston, and Prof. Harrison Allen is yet to lecture.

The important event of the year was the holding of the twenty-seventh exhibition of the Institute. In order that a statement of this event could be presented to you in a succinct form the chairman of the Committee on Exhibition, Mr. Wm. P. Tatham, was requested to draw up a report, which was accepted by the Board of Managers and ordered to be made a part of this report. It is as follows:

To the Board of Managers of the Franklin Institute:

The Committee on Exhibitions, which, under existing By-Laws, is a Committee of your body, respectfully report:

That the Exhibition of 1874, held to celebrate the Fiftieth year of the Foundation of the Institute, proved worthy of the occasion, whether its success be tested by the number and excellence of the articles exhibited, the large concourse of visitors, the instruction and gratification it afforded to the community, or by the pecuniary results.

The first movement towards the Exhibition was at the stated meeting of the Institute held February 18, 1874, when, on motion of Mr. G. Morgan Eldridge, the subject was referred to the Committee on Exhibitions.

The Committee lost no time in addressing a letter to J. Edgar Thompson, Esq., late President of the Pennsylvania Railroad Company, making an application for the use of their depot on Market Street, between Thirteenth and Juniper Streets, for the purpose of an Exhibition. This application having been laid before the Board of Directors, and favorably entertained by it, the President (Mr. Thompson) was authorized to act, which he did by the letter of his assistant, Strickland Kneass, Esq., dated the 17th of March, placing

the depot at our disposal during the months of September and October, 1874. Thus, by the exercise of the greatest liberality on the part of the Pennsylvania Railroad Company, the Institute had, for the first time for many years, the opportunity of holding an Exhibition under promising conditions.

At the stated meeting of the Institute held the 18th of March, resolutions were adopted, requesting the Board of Managers to hold an Exhibition, and to secure a guarantee fund to indemnify the Institute against loss. This condition having been fulfilled, public announcement was made upon the 14th of April, that the Exhibition would be held from the 6th to the 31st of October, thus allowing thirty-five days for the transformation of the building and preparation for the Exhibition, and twenty-six days for the Exhibition itself.

Your Committee, before this time, had been strengthened by adding to it all the members of the Board of Managers, and the assistance of the Institute at large was invoked, resulting in the appointment by the President of one hundred members, for the purpose of forming Committees on the various classes of Exhibits. Some of these gentlemen were appointed upon the standing sub-committees, and acted with the greatest ability, zeal and usefulness. The Class Committees were composed, when possible, of members associated with the various trades and industries. It was made their duty to stimulate exhibitors in their respective classes, and thus to induce an Exhibition which would command the public attention and secure success.

These Committees were also requested to nominate the Judges in their respective classes. It is believed that the policy thus adopted for the first time, had a large influence upon the ultimate success of the Exhibition.

The Committees on Rules, Transportation, and Publication having completed their preparations, a pamphlet containing an address by the Board of Managers, with the necessary information and the Rules governing the Exhibition, was issued upon the 13th of May. The duties of the Committee on Space then began, and were continued all summer, culminating at the opening of the Exhibition. On the 1st of July, Mr. J. B. Knight, who had been actively performing committee work as a member of the Institute, was appointed General Superintendent of the Exhibition.

The Pennsylvania Railroad Company had conditionally promised the use of the depot from the first of September, and the surveys and

preliminary arrangements were made by the Sub-Committee on Building and Machinery to accomplish its work in the interval of time allowed it. But, actually, the Company abandoned the depot upon the 19th of August, and we were placed in possession twelve days before the time specified. The advantage thus gained was never lost. The Sub-Committee pushed the work with such energy that the Exhibition building was ready to receive goods about the 1st of September, instead of the 14th, as advertised.

The Committee had been led to expect that the patent boilers to be exhibited would be sufficient to run the machinery of the Exhibition; but it became apparent towards the end of September that this reliance would fail, and arrangements were made to secure other boilers, which were placed outside of the building. In consequence of this disappointment, the steam-power was not ready until the day after the opening of the Exhibition. Considering, however, the great number of Exhibits and the unusual number of machines in motion, the general preparation of this Exhibition was unusually prompt.

The Exhibition was opened by the Governor of the State of Pennsylvania, upon the day appointed, and attracted the sustained attention of the public to such an extent, that it was deemed advisable to continue it open for twelve days longer than was originally designed.

The principal reasons for this extension (which on general principles should be avoided) were, that the great crowds of visitors made it impossible for the Judges to perform their duties satisfactorily, and the same cause excluded from the Exhibition many persons who had bought tickets of admission, over 12,000 of which were outstanding in the hands of the community at the end of October.

The greatest number of tickets paid for and unused, at any one time, was 31,973, upon the 20th of October.

At the close of the Exhibition the number still outstanding was 4120.

The whole number of paying visitors was 267,638, besides members of the Institute, their ladies, and minors, and persons admitted on complimentary tickets issued to the press and to others whose liberality it was desired to recognize. Making due allowance for these, it may be said that the Exhibition was visited by one-third of our population. The number of applications for space was 1528. The number of entries for exhibition, many of them covering numerous items and large displays, was 1251. The number of steam boilers

in operation was 9, of 316 horse-power in the aggregate, consuming 267 tons of coal. There were 3 steam engines driving shafting, 22 driving pumps, and 11 driving particular machines. The whole number of steam engines at work, or in motion, was 46. The whole number of machines in motion was 281.

Some of the displays were of peculiar excellence. The photographs were particularly good, and would class strictly with the fine arts; but besides these, the variety and beauty of the chemicals displayed, the wonder working of the sewing machines, the brilliancy of the saws, the splendor of the chandeliers, the rapidity of the printing press, the precision of movement of the machine tools, and the truth and finish of the paper cylinders, appealed not only to our appreciation of the usefulness of these exhibits, but in addition lent to them the charms and influences of the fine arts.

As a further testimony to the excellence of the exhibition, it appears that although the rule upon the subject of premiums, prepared by the proper committee and adopted by the Board of Managers, was more severe than usual, the premiums awarded under it were more numerous than at any previous exhibition; being 201 silver medals, 228 bronze medals, and 222 certificates of honorable mention, in all 651, while many subjects were recommended to the Committee on Science and the Arts, for the award of the special medals of the Institute.

It is impossible now to state the exact financial results of the exhibition, because some bills are not yet adjusted, and some expenses are still to be incurred. We received for entry account, pulley account, and sale of tickets, $91,947.61, and our expenses are already $37,664.95, and it is estimated they will reach $39,775.95, leaving the sum of $52,171.66 as net profits. It is proposed to publish a full report, embracing the reports of the judges and all matters connected with the Exhibition.

The results of our efforts prove the readiness of our people to visit a meritorious Exhibition, and should encourage the Managers of the great Centennial in hoping for a magnificent success to their undertaking.

It remains to record our thanks to those persons whose liberality, or kindness has assisted us in various ways. The thanks of the Institute are due to the authorities of the Pennsylvania Railroad Company, whose liberality already noticed was followed by repeated acts

of like character and by acquiescence in all our requests; to the subscribers to the guarantee fund, who afforded us the first encouragement, a like acknowledgment is none the less due, because the result has exempted them from all liability.

We owe our thanks also to His Honor, the Mayor of the City, for an efficient police force during the Exhibition, and to all the Departments of the City government to whose good offices we were indebted; to the Navy Department for the flags used in decoration, and to the Treasury Department for the deposit of the life boat at our request; to Messrs. Morris, Tasker & Co. for the liberal use of their gas pipes, and to Messrs. Wm. C. Allison & Sons for a like use of steam pipes, to the American Dredging Co. for the free loan of a new boiler, and to Messrs. I. P. Morris & Co. for a like favor.

It is proper, also, to thank many of the exhibitors who incurred considerable expense merely to serve the purposes of the Exhibition. Among these were Messrs. Jacob Naylor, Andrew Watson, Neafie & Levy, and Robert Wetherill, exhibitors of steam engines; Messrs. Wm. Sellers & Co. and Geo. V. Cresson, exhibitors of shafting; Messrs. Thomas J. Rorer, Sellers & Bros., and Alexander Bros., exhibitors of belts; all used in driving the machinery of the Exhibition. Our thanks are also due to Mr. Thomas Shaw, who at our suggestion exhibited a much larger propeller pump and cataract than he had designed; to Mr. Charles H. Brown for a pump used to supply the outside boilers; to Messrs. Dyott & Co. for the liberal loan of street and door lamps; to Messrs. Cornelius & Sons, Baker, Arnold & Co., Thackara, Buck & Co., and the American Reflector Co., for the loan of gas fixtures; to Messrs. I. P. Morris & Co., who at our request built the fast Bullock printing press and engaged to carry it until sold, in order that it might be placed in the Exhibition; to the judges (not necessarily members of the Institute), who brought to their delicate tasks a special knowledge of the subjects committted to them, and performed their duties with the greatest integrity, assiduity and judgment; and finally, to the public press, which, recognizing the public nature of our enterprise, was a faithful interpreter of the kind feeling of the community towards us.

The labor performed by the sub-committees, particularly by those upon Building and Machinery, and upon Space, were of a character which it would be impossible to buy.

The officers employed in the Exhibition performed their duties with the greatest efficiency, and the Committee take especial pleasure in testifying to the ability, energy and tact of the General Superintendent.

W. P. TATHAM,
Chairman Committee on Exhibitions.

Philadelphia, Jan. 18, 1875.

Your Board submit with this report an official statement of the awards to the exhibitors as confirmed by them, premising the list by the explanation that in the report to be published, which will embody the reports of the Judges, much valuable matter will be given, and mention will be made of all articles entered in competition, many of those not receiving premiums being favorably mentioned.

All of which is respectfully submitted.

By order of the Board.

COLEMAN SELLERS, *President.*

The Report of the Board as read was accepted, and ordered to be published in the JOURNAL.

Mr. S. Lloyd moved that the publication of that portion of the Report referring to the awards be withheld from the public press until certain matters in dispute should be satisfactorily adjusted, and supported the motion in an address, setting forth his reasons therefor. The motion was seconded by Mr. Woodruff, who remarked that many of the dissatisfied exhibitors had not as yet had the opportunity to enter reclamation.

The motion was put to the meeting and lost.

The Actuary then reported the minutes of the Board of Managers, and of the several Standing Committees. He also reported that at the stated meeting of the Board, held Wednesday, the 13th inst., the following donations to the Library had been reported, viz. :—

Journal of the Chemical Society for August, September and October, 1874. From the Society.

Journal of the Statistical Society for September, 1874, with a General Index to Vols. 26 to 35, 1863 to 1872. From the Society.

The Manchester Steam Users' Association for the Prevention of Steam Boiler Explosions. Chief Engineer's Monthly Report for September, 1874. From the Association.

Proceedings of the Scientific Meetings of the Zoological Society of London for the year 1874. Parts 2 and 3. From the Society.

Proceedings of the Royal Institution of Great Britain, Vol. 7, Parts 3 and 4. From the Institution.

Annales des Ponts et Chaussées for September, 1874. From the Editor. Paris.

Annales de Chimie et de Physique for September, 1874. From the Editor. Paris.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale, Vol. 1, Nos. 9–10. From the Society.

Remarks to accompany Monthly Charts of Meteorological Data for Square 3. From the Meteorological Office. London.

Quarterly Weather Reports of the Meteorological Office. Part 4, October to December, 1871. Part 3, July to September, 1873. From the Meteorological Office.

Charts of Meteorological Data for Square 3, Lat. 0° to 10° N., Long. 20° to 30° W. From the Meteorological Office.

Report of the Commissioner of Education for 1873. Washington, 1874. From the Commissioner.

Monthly Notices of the Royal Astronomical Society, Vol. 35, No. 1, November, 1874. From the Society. London.

Annales de Chimie et de Physique for October and November, 1874. From the Editor. Paris.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale for November, 1874. From the Society. Paris.

Publishers' Trade List Annual, embracing the full Trade Lists of American Publishers. From J. B. Lippincott & Co. Philadelphia.

Forty-first Annual Report of the Royal Cornwall Polytechnic Society, 1873. From the Society.

Smithsonian Contributions to Knowledge 281, on the General Integrals of Planetary Motion. By Simon Newcomb, Professor of Mathematics, U. S. N. From the Smithsonian Institution.

Treatise on Elements of Mechanics. By John W. Nystrom, C. E. From the Author.

On the Diurnal Inequalities of the Barometer and Thermometer. By W. W. Rundell, F. M. S. From the Author.

Dr. Robert E. Rogers, as Chairman of the Special Committee to prepare a suitable testimonial to the Pennsylvania Railroad Company, in acknowledgment of their kind offices in placing the Freight Depôt at Thirteenth and Market Streets at the disposition of the Institute

for Exhibition purposes, presented the following preamble and resolutions, which, on motion, were unanimously adopted, viz.:

WHEREAS, The Franklin Institute, recognizing the great progress made in the Mechanic Arts since the holding of the last Exhibition in 1858, and feeling impressed with the importance of having an Exhibition during the autumn just passed, not only for the immediate benefit expected to the Institute and to the community at large, but also as a preparation for greater results at the Centennial, was anxiously seeking a building suitable for such an Exhibition,

AND WHEREAS, The Pennsylvania Railroad Company, alive to the interests of the City and the State, with its accustomed public spirit and liberality, placed at the service of the Institute without rent or charge of any kind, their spacious Depot Building at Thirteenth and Market Streets,

AND WHEREAS, Without such liberality the Institute could not have held its recent Exhibition; therefore,

Resolved, That the cordial thanks of the Franklin Institute be tendered to the President and Board of Directors of the Pennsylvania Railroad Company for this act of generous kindness, which has enabled the Institute to hold an Exhibition surpassing in attractiveness and success any it has held in previous years.

Resolved, That the Institute will ever hold in grateful recognition the cordial sympathy manifested by the Pennsylvania Railroad Company in the great interests which the Franklin Institute represents.

Resolved, That the Institute desires to express its thanks also to the subordinate officers of the Pennsylvania Railroad Co. for the cheerful co-operation which it has received at their hands.

R. E. ROGERS (Ch.),	COLEMAN SELLERS,
W. P. TATHAM,	CHAS. S. CLOSE,
J. B. KNIGHT,	HECTOR ORR, *Committee.*

Mr. J. W. Nystrom, on behalf of the Committee on New Site and Building, reported progress. The report of the Secretary was, on motion, passed over.

Under the head of deferred business, the resolution of Mr. Shaw to appoint a committee of appeal to hear and adjust disputed matters growing out of the awards made at the late exhibition; and likewise, the amendment of Mr. Burleigh, to refer the subject to arbitration before the Committee on Science and Arts, both of which were

postponed from the last stated meeting, were called up for consideration.

Mr. Shaw urged the passage of the resolution as offering the only satisfactory solution of existing difficulties, and employing substantially the same arguments as those advanced at the previous meeting.

Mr. William P. Tatham deprecated any further agitation of the subject. He spoke earnestly against the resolution, dwelling upon the patient labor that had been bestowed upon the reports of the Judges by the Board, and of the impossibility of satisfying every one in an enterprise of the magnitude of the late exhibition.

Mr. Hector Orr spoke of the inutility of handing the subject over to the Committee on Science and Arts. The amendment of Mr. Burleigh to so refer the resolution was then put to vote, and lost.

Mr. Orr then offered the following amendment to the resolution, viz.:—

WHEREAS, Certain complaints have been offered against the awards and decisions of the proper authorities of the late Industrial Exhibition held by the Franklin Institute,

AND WHEREAS, The ascertainment and correction of said grievances are alike the duty and interest of the Institute, therefore

Resolved, That a committee of members be appointed to hear the above charges and report thereon to the Institute as early as possible, *provided* that no Manager, nor Judge, nor any complaining depositor shall be eligible to serve on said Committee, but all these excluded classes shall be entitled and invited to testify before said Committee upon the subjects involved.

The amendment was discussed by Messrs. Shaw, Gray, Close and the mover, and on being put to the house was lost.

Mr. Frederick Fraley next addressed the meeting in opposition to Mr. Shaw's resolution, which he characterized as being entirely without precedent, and revolutionary in its character. He moved the previous question, which being duly seconded was put to vote and ordered. The resolution was lost.

A communication of Mr. Gravenstine was then called up under deferred business, but was withdrawn.

Mr. William B. LeVan, under new business, offered the accompanying amendments to the By-Laws, which in accordance with Article XVI., were laid over until the stated meeting of February, viz.:

Resolved, That Section 3, Article 5, of the By-Laws be amended by changing the hour of opening the polls from 4 o'clock to 3 o'clock

P. M., and the hour of closing the polls from 8 o'cock to 9 o'clock P. M.

Resolved, That Section 1 of Article 5 of the By-Laws be amended by adding to the first sentence the following: "And provided further that no member shall be eligible for re-election as a Manager or Vice President, for the period of one year after his term of office has expired."

Mr. Thomas Shaw then moved that a committee be appointed to prepare and submit to the Institute the draft of a section to the By-Laws making provision for a Board of Appeal for the adjustment of difficulties growing out of the exhibitions of the Institute.

Mr. Lippman amended the resolution by the clause, "that five members be appointed by the meeting, who, in conjunction with a similar committee from the Board of Managers, shall consider the expediency of revising or amending the modes, rules and regulations governing awards, and report to the Institute upon the system which they shall deem the most perfect."

The amendment and resolution were respectively put to vote and lost.

Mr. Sellers then resigned his seat to the senior Vice-President, Mr. Bloomfield H. Moore, and after calling attention to the somewhat dilapidated condition of the chair which he, as well as numerous predecessors, had so long occupied, moved that the proper authorities be directed to purchase a new one for the incoming President. Carried.

Mr. B. H. Moore next occupied the floor eulogizing the services of a number of gentlemen who were active in contributing to the success of the late exhibition. He offered the following resolution:

Resolved, That the thanks of the Institute be tendered to Messrs. Tatham, Close, Knight, Bullock, Sartain, and others, for their services in behalf of the Exhibition. Carried.

The judges of the election next announced the result of the balloting for officers, whereupon the President declared the following gentlemen to have been elected to the offices opposite their names, viz:

President, Professor Robert E. Rogers.

Vice-President, Charles S. Close.

Secretary, J. B. Knight.

Treasurer, Frederick Fraley.

Managers to serve three years, Coleman Sellers, William P. Tatham, Washington Jones, Pliny E. Chase, J. M. Wilson, Dr. Isaac Norris, Jr., George F. Barker, Theodore D. Rand.

Manager to serve two years, Alexander Purves.

Auditor, James H. Cresson.

A motion was made, and unanimously carried, that the thanks of the Institute be tendered to Mr. Coleman Sellers, the retiring President, for the efficient and satisfactory manner in which he had presided over the meetings of the Institute, during his term of office.

A vote of thanks to the other retiring officers, was also unanimously carried.

Whereupon the meeting adjourned.

WILLIAM H. WAHL, *Secretary.*

FRANKLIN INSTITUTE EXHIBITION, 1874, AWARDS OF PREMIUMS.

I.—Agricultural Implements.

SILVER MEDAL.

353	Graham, Emlen & Passmore, Philadelphia,	The Philadelphia Lawn Mower.
981	Samuel L. Allen & Co., "	The Planet Drill & Wheel Hoe.

BRONZE MEDAL.

94	Wm. L. Boyer & Bro., Philadelphia,	Burt's Union Railway Horse Power.

HONORABLE MENTION.

254	B. Gill & Sons, Trenton, N. J.,	Rye Thresher.
706	John M. Hess, Philadelphia,	Pat. Self-Watering Hanging Basket.

II.—Agricultural Productions.

SILVER MEDAL.

522	Duryea Glen Cove Starch Co., New York,	Improved Corn Starch.
20	Duryea Glen Cove Starch Co., New York,	Satin Gloss Starch.
489	C. J. Fell & Bro., Philadelphia,	Spices and Mustard.

BRONZE MEDAL.

78	Lagomarsino & Cuneo, Philadelphia,	Maccaroni, Verm'li & Fancy Paste.
669	E. M. Dexter, Philadelphia,	Ornamental Confectionery.
237	G. Boyd, Philadelphia,	Grubb's Aroma Coffee Cooler.
238	" "	Aroma Coffee Roaster.
1492	H. Troemner, Philadelphia,	Coffee Mill.
209	Mrs. Joshua Wright, Philadelphia,	Mince Meat.
416	D. Carrick & Co., "	Crackers, Cakes and Biscuits.
664	Theo. Wilson & Co., "	Crackers and Cakes.
740	Godfrey Keebler, "	Cakes and Crackers.
946	Woodward, Garrett & Co., Philadelphia, for Edw. Holbrook, M'f'r, Louisville, Ky.,	Manufactured Tobacco.
267	S. Fuguet & Sons, Philadelphia,	Seidenberg & Co's, Key West, Havana Cigars.
1451	Frishmuth, Bro. & Co , Philadelphia.	Fine Cut Tobacco, "Luxury."

HONORABLE MENTION.

270	Atmore & Sons, "	Plum Puddings.
1309	John A. Place, Phila., for F. E. Smith Co., Manufacturer, New York,	Crushed White Wheat.
980	Lagomarsino & Cuneo, Philadelphia,	Farina.

III—Arms and Military Goods.

BRONZE MEDAL.

951	Wm. Wurflein, Philadelphia,	Creedmore or Parlor Rifle.

HONORABLE MENTION.

1019	John Krider, Philadelphia,	Guns and Sporting Instruments

IV.—Books and Stationery.

SILVER MEDAL.

742	J. B. Lippincott & Co.,	Blank Books and General Binding.
743	Byron Weston, Dalton, Mass.; J. Shoemaker, Agent,	Linen Ledger and Record Paper.
39	Jos. E. Hover & Co., Philadelphia,	Chemical Writing Fluids.
699	Wm. F. Murphy's Sons, "	Blank and Copying Books.
1493	Wm. Mann, "	Copying Paper.

BRONZE MEDAL.

331	Crane Bros., Westfield. Mass.,	Various articles m'f'd fr. Paper Pulp.
942	Jno. E. Potter & Co., Philadelphia,	Potter's CompleteBible Encyclopedia.
455	Ig. Kohler, "	Book Binding.
644	Esterbrook Steel Pen Co , Camden, N. J.,	Steel Pens.
686	Porter & Coates, Philadelphia,	Book Binding.
1512	J. B. Lippincott & Co., Philadelphia,	Book Printing.
803	Fry's Engraving Office, "	Book Binders' Tools and Dies.
44	Altemus & Co., "	Photograph Albums.
1003	Geo. W. Woolley, "	Pat. Reservoir Pen.

HONORABLE MENTION.

264	Lipman Manufacturing Co., Philadelphia,	Hover's Carbonized Writing Paper.
941	John E. Potter & Co., "	Brown's Self-Interpreting Bible.
943	" " "	Blackwood's Comprehensive Bible.
403	T. Ellwood Zell, "	Books of Reference.
819	A. J. Holman & Co., "	Illus. Fam. Bibles & Photo. Albums.
861	Chas. Magarge & Co., "	Jessup & Laflin's Writing Paper, (Westfield, Mass.)
1354	Louis Dreka, "	Dictionary Blotter.
265	Lipman Manufacturing Co., "	Lipman's Pat. Eyelet Machine.

V.—Boots and Shoes.

SILVER MEDAL.

303	C. Benkert & Son, Philadelphia,	Gents' Hand-made Boots and Shoes.

BRONZE MEDAL.

2	Thos. R. Evans, Philadelphia,	American Gaiter.
983	Saller, Lewin & Co., "	Machine-made Boots and Shoes.
184	M. A Erskine & Co., "	Ladies' Hand-made Boots and Shoes.
1021	Royal & Reed, "	Ladies', Misses', and Children's Machine-made Boots and Shoes.

HONORABLE MENTION.

207	Wm. F. Bartlett, Philadelphia,		Gents' Boots and Shoes.
483	Porous Waterproofing Co., Philadelphia,		Water Proof Boots and Shoes.
936	Wm. G. Schoell,	"	Hand-made Seamless Boots & Shoes.
1484	A. C McKnight,	"	Water Repellant Boots and Shoes.
1236	Allen, Gates & Bro.,	"	Ladies' Machine Sewed Lined Boots and Shoes.

VI.—Cabinet Ware and Upholstery.

SILVER MEDAL.

411	Hale, Kilburn & Co., Philadelphia,		E. E. Everett's Pat. Fold. Bedstead.
208	Jas. S. Earle & Sons,	"	Mirrors, Picture Frames, etc.
219	Jos. W. Cooper,	"	Fancy Walnut Brackets, etc.
524	Allen Bro's,	"	Parlor Furniture, etc.

BRONZE MEDAL.

336	Fred. Boland, Philadelphia,		Mirrors and Picture Frames.
252	J. A. Bancroft & Co., Philadelphia,		Imp. Rever. Settee, T. J. Close, Pat.
521	R. W. P. Goff,	"	Fancy Walnut Brackets, etc.
311	Chas. W. O'Hara,	"	Comfortable Chair.
415	A. Lowe & Co.,	"	Mirror and Picture Frames, etc.
745	Hutchins & Mabbett,	"	Gardner's Pat. 3 ply Veneer Chairs.
1352	Thos. Potter, Sons & Co.,	"	Knapp's Spring Balance Roller.
410	Hale, Kilburn & Co.,	"	Pat. Flexible Wood Seat Chair.
414	Kilburn & Gates,	"	Cottage Furniture.
549	H. B. Coyle,	"	Centennial Iron Bedstead.
61	Samuel McCracken,	"	Inlaid Centre Tables.
879	Cyrus Horne,	"	Burial Casket.
3	W. B. Coates,	"	Convertible Folding Lounge.

HONORABLE MENTION.

412	Hale, Kilburn & Co., Philadelphia.		H. W. Curtis, Pat., Walnut Mats for Picture Frames.
201	Salem Shade Roller Mfg. Co., exhibited by E. S. Johnston,		Window Shade Balance Spring Roller Attachment.
149	C. Faser, Philadelphia,		Gilt Frame Mirror, fine finish.
175	Carrington, DeZouche & Co., Philadelphia,		Handsome Display of Curtains.
188	W. Heacock, Philadelphia,		Fine Finish of Furniture.
413	Hale, Kilburn & Co., Philadelphia,		Walnut Looking Glass and Picture Frames.
125	Walter & Stoeltz, Philadelphia,		Show Case.
433	G. J. & J. A. Henkels, Philadelphia,		Design and Fine Finish of Chamber Furniture.
689	Jno. McKinley,	"	Parlor Furniture.
638	S. B. Register, Philadelphia,		Furniture.
1426	James Irons,	"	Show Cases.

VII.—Carpets, Oil Cloths, and Floor Coverings.

SILVER MEDAL.

1105	Bromley Bro's, Philadelphia,		Patent Imperial Damask Venetian Carpets.
400	Thos. Potter, Son & Co., Philadelphia,		Table and Enameled Oil Cloths.
59	Reeve L. Knight & Son,	"	Display of Carpets from various Mfrs.
1257	" "	"	A. Smith & Son, Axminster Carpets.

BRONZE MEDAL.

709	John Bromley & Sons, Philadelphia,	Ingrain and Damask Carpets.

HONORABLE MENTION.

516	G. W. Chipman & Co., Boston, Mass.,	Carpet Linings.

VIII.—China, Glass, and Porcelain.

SILVER MEDAL.

728	Ward & Co., Philadelphia, for Lenox Plate Glass Co., Mass.,	Rough Plate Glass.
1153	J. & G. H. Gibson, Philadelphia,	Stained Glass.

BRONZE MEDAL.

224	Jas. K. Kerr & Bro's, Philadelphia,	Decorations on China.
490	J. K. Dunham, Agent for Boston & Sandwich Glass Co.,	Glassware.
595	Whitall, Tatum & Co., Philadelphia,	Glassware.
900	S. G. Boughton, Philadelphia, Agent for New England Glass Co.,	Glassware.
708	Dempsey Wicker Covered Glassware Co., Philadelphia,	Wicker Covered Bottles.

HONORABLE MENTION.

174	J. E. Jeffords & Co., Philadelphia,		Yellow, Rockingham, Birmingham, and Lava Wares.
213	Wm. Holzer,	"	Display of Glassware, Medical and Philosophical Apparatus.
398	Jas. K. Kerr & Bro's,	"	Engraving on Glass.
1375	Hartell & Letchworth,	"	Sand Blast Glass Work.
1424	Cohansey Glass Co.,	"	Fruit Jars.
120	Richard C. Remmey,	"	Chemical Stone Ware.

IX.—Coach Work.

SILVER MEDAL.

1292, 1293, 1294	Wm. D. Rogers & Co., Philadelphia,		Carriages.
79	W. Garner & Son,	"	Light Business Wagon.
43	Fulton & Walker,	"	Omnibus.
431	" "	"	Express Wagon.
301	Geo. Lengert & Son,	"	Truck Wagon.
235	Harry J. Shill,	"	Children's Carriages.
715	Benezet & Co.,	"	Coach, Carriage, and Wagon Springs.
198	Wm. Burwell & Bro.,	"	Carriage Mountings.

BRONZE MEDAL.

277	Wm. D. Gardner, Philadelphia,		Carriages.
87	S. P. Campbell & Co.,	"	Children's Carriages.
909	W. & H. Rowland,	"	Coach, Carriage, and Wagon Springs.

HONORABLE MENTION.

519	S. W. Jacobs & Son, Philadelphia,		Carriages.
481	Jas. Fleming,	"	Carriages.
527	Weaver & Lyle,	"	No-top Wagon.
164	Geo. K. Childs,	"	One-man Wagon.
262	McLear & Kendall.	"	Carriages.
334	Collings Bros.,	"	Carriages.
882	George Tiel,	"	Child's Sleigh.
15	The Phila. Axle Works,	"	Carriage and Wagon Axles.
1457	Advena & Heald,	"	Carriage and Wagon Axles.
616	Hoopes Bro's & Darlington,		Carriage and Wagon Wheels.
1414	Hoopes Bro's & Darlington, West Chester, Pa.,		Bent Carriage Material.
1208	W. Garner & Son, Philadelphia,		Hand-made Wheels.
988	S. D. Mott, Milford, Pa.,		Pat. Guiding Attachment for Coasting Sleigh.

X.—Coal and Minerals.

SILVER MEDAL.

662	James C. Hand & Co., Philadelphia,	Corundum, from Pa. Corundum Co.

HONORABLE MENTION.

1364	Denver and Rio Grande R. R. Co.,	Coal and Coke.

XI.—Combs and Brushes.

SILVER MEDAL.

928	Chas. Brintzinghoffer, Philadelphia,	Leather Back Horse Brush.

BRONZE MEDAL.

635	Geo. W. Metz & Sons, Philadelphia,	Fine toilet and other Brushes.

XII.—Copper, Brass, Plumbers' and Tin Ware.

SILVER MEDAL.

560	Joseph L. Travis, Philadelphia,	J. & H. Jones' Ne Plus Ultra Water Closet.
1070	Miller & Krips, "	Brass Castings.

BRONZE MEDAL.

112	Cooper, Jones & Cadbury, Philadelphia,	Water Closet Valve.
280	" " " "	Compression Bibb Cocks.
559	Joseph L. Travis, "	Combination Shower Cock.
1249	John P. Schaum, Lancaster, Pa.	Copper Kettle.
1222	Chas. Burnham & Co., Philadelphia,	Patent Safety Can.
1320	W. S. Bate, Philadelphia,	Patent Wash Stand Faucet.
1480	Philadelphia Smelting Co., Philada.	Unfinished Brass & Bronze Castings.
1101	N. & G. Taylor Co., "	Decorated Tin Plates.

HONORABLE MENTION.

124	R. D. O. Smith, Washington, D. C.	Odorless Water Closet and Urinal.

XIII.—Cotton and Woolen Goods.

SILVER MEDAL.

1503	Washington Mills, Lawrence, Mass., Jas. W. Dayton, Agent,	Superior Worsted Coatings.
1504	Washington Mills, Lawrence, Mass., Jas. W. Dayton, Agent,	Superior Colors in Shawls and Dress Goods.
1505	Burlington Woolen Co., Winooski Falls, Vt., Jas W. Dayton, Agent,	Superior Wool-dyed Kerseys.
1506	Burlington Woolen Co., Winooski Falls, Vt. Jas. W. Dayton, Agent,	All-wool Black and colored Cloths, Doeskins and Beavers.
103	Fiss, Banes & Erben, Philadelphia,	Jennapped Worsted Yarn.
104	" " " "	No. 120 Worsted Yarn.*
729	David Trainer & Sons, Linwood, Pa.	Superior Extra Omega Tickings.
1227	Willimantic Linen Co., Colladay, Trout & Company, agents,	Spool Thread.
85	S. B. & M. Fleisher,	Star Alpaca Braids.
16	Aub, Hackenburg & Co.	Machine and Sewing Silks. Black and White
478	Belding Bros. & Co., L. C. Hall, Jr. & Co., Agents,	50 and 100 yards Sewing Silks, plain and Fancy Colors.

* The exhibit of No. 120 Worsted Yarn has been referred to the Committee on Science and Arts, with recommendation that it be awarded one of the higher medals of the Institute.

BRONZE MEDAL.

651	Wood & Haslam,	Quilts.

HONORABLE MENTION.

1059	David S. Brown & Co. (Gloucester and Ancona Printing Co.,)	Display of Prints.

XIV.—Dental and Surgical Instruments.

SILVER MEDAL.

62	S. S. White, Philadelphia,	Artificial Teeth.
779	D. W. Kolbe, "	Artificial Limbs.
1517	" " "	Surgical Instruments.
1478	S. S. White, "	The S. S. White Dental Engine.

BRONZE MEDAL.

596	J. B. Seeley, Philadelphia,	Trusses.

HONORABLE MENTION.

785	J. B. Seeley, Philadelphia,	Silk Elastic Surgical Bandages.
903	Geo. P. Pilling, "	Surgical and Dental Instruments.

XV.—Drugs, Dye Stuffs and Chemicals.

SILVER MEDAL.

84	Rosengarten & Sons, Philadelphia.	Purity of Chemical Preparations.
123	Powers & Weightman, "	For Fine Display, General Excellence and Purity of their Com. Chemical Preparations.*
361	Penna. Salt M f'g Co., "	Fine Display and Purity of Sodium Bi-Carbonate.
25	Joseph Wharton, Camden, N. J.,	Superiority of Nickel and Nickel Compounds.
58	Mellor & Rittenhouse, Philadelphia,	Licorice.
24	Chas. Lippincott & Co., "	Soda Water Fountains.

BRONZE MEDAL.

1520	J. S. & T. Elkinton, Philadelphia,	Silicate of Soda.
256	Henry Bower, "	Excellence of Glycerine and other Chemicals.
352	J. M. Sharpless & Co., "	Purity of Dye Stuffs & Dye Woods.
357	Kurlbaum & Co., "	Purity and Beauty of Chemical Prep.
1333	Wm. Gulager, Philadelphia, for New England Glass Co., M'f'rs, Boston, Mass.,	Superior Glass Makers Litharge.

HONORABLE MENTION.

808	Wm. Gulager, Philadelphia, for Hartman Laist & Co., M'f'rs, Cincinnati, O.,	Excellent qualities of Glycerine.
1213	Harrison Bros. & Co., Philadelphia,	Excellence of Oil of Vitriol.
1369	Wm. B. Burke & Co., "	Hand and Machine-made Corks.
1123	McIlvaine & Bros., "	Uniformity of pulverization of Drugs and Spices.
585	Hansell & Bros., "	Apple Vinegar.
386	J. C. Hurst & Son, "	Burdict's Oil Polish Blacking.

* Referred to Committee on Science and the Arts, with a recommendation to award the Elliot Cresson Gold Medal.

XVI.—Fine Arts and Photography.

SILVER MEDAL.

1486	F. Gutekunst, Philadelphia,	Glacé Photographs.
64	" " "	Large Plain Photographs.
383	Broadbent & Phillips, Philadelphia,	Large Crayon Photographs
1004	Trask & Bacon, "	Plain Cabinet Pictures.
663	A. H. Hemple, "	L'ge Photo's of Engines & Machinery
572	Wm. G. Entriken, "	Oscillating Enameller for burnishing Photographs.
568	Jno. Carbutt, Sup't American Photo-Relief Printing Co., Philadelphia,	For Excellence in Lantern Slides and the Pictures of Bone, Tissue, Machinery, etc., by Woodbury Type Process.
1056	New York & Boston Sand Blast Co., Gorham Blake, Agent,	Tilghman's Etching Process on Glass.
846	Samuel Sartain, Philadelphia,	Steel Engravings.
182	Jas. R. Osgood & Co., Boston, Mass.,	Heliotypes—an Improved Method of Photo-Mechanical Printing.
698	Jas. W. Lauderbach, Philadelphia,	Wood Engraving.
570	Breuker & Kessler, "	Lithographed Bonds, etc.
818	Thos. Hunter, "	Chromos.
1519	Jas. S. Earle & Sons, "	Display of Rogers' Statuette Groups.
439	Potsdamer & Co., "	Lithographic Engraving.

BRONZE MEDAL.

1495	Broadbent & Phillips, Philadelphia,	Glacé Photographs.
657	Suddards & Fennimore, "	Large Colored Photographs.
647	James Cremer, "	Stereoscopic Views.
666	F. Langenheim, "	Col'd Albumen Magic Lantern Slides
114	Robert Steele, "	Illuminated Show Cards.
226	Louis Dreka, "	Stationery—Artistic Design & Workmanship.
385	Wells & Hope Co., "	Wells' Pat. Metallic Adv'ng Signs.
231	Mason & Co., "	Stationery—Artistic Design & Workmanship.
1149	Mrs. A. Pilkington, "	Wax Flowers and Preserved Geranium Leaves.
18	Janentzky & Co., "	Artists' Materials, Oil Colors, etc.
371	Estate of Thomas Heath, "	Plaster Statuary.
1068	Martha A. Torrey, "	Marking with Indelible Ink, Original Designs with Quill Pen.
1465	Geo. A. Rowe, "	Cameos and Intaglio Cuttings on Precious Stones, and Frame of Impressions in Wax.
915	Longacre & Co., "	Engraving on Wood.
19	Janentzky & Co., "	Water Colors.

HONORABLE MENTION.

1485	F. Gutekunst, Philadelphia,	Large Crayon Photographs.
122	P. E. Chillman & Co., Philadelphia,	Glacé Photographs.
275	Robt. Newell & Son, "	Acid proof Photo-Ware.
722	Benj. Linfoot, "	Architectural Water Color Drawing.
796	Crosscup & West, "	Wood Engraving of Machinery and Buildings.
281	Benerman & Wilson, "	Photographic Publications.
656	W. F. Geddes' Sons, "	Fruit and Can Labels in colors.

XVII.—Gents' Furnishing Goods, Canes and Umbrellas.

SILVER MEDAL.

155	Wm. A. Drown & Co., Philadelphia,	Umbrellas.
377	Ridgway & Oliphant, Philadelphia,	Gloves and Gauntlets.

BRONZE MEDAL.

1461	J. Herzberg & Bro., Philadelphia,	Patent Notch on Umbrella Frames.

HONORABLE MENTION.

163	Wanamaker & Brown, Philadelphia,	Clothing.
223	E. O. Thompson, "	Pantaloons and other Garments.
621	Richard Eyre, "	Shirts.
178	Carpenter & Latimer, "	Shirts.
325	Shedaker & Lindsey, "	Shirts.
255	F. Sachse & Son, "	Shirts.

XVIII.—Gold and Silver Ware, Plated Ware and Jewelry.

SILVER MEDAL.

157	Hastings & Co., Philadelphia,	Gold and Silver Leaf and Gold Foil.
202	Louis H. Spellier, Doylestown, Pa.	Clock, and Improvements therein.
1259	Hietel Bros., Philadelphia,	Improvement in Watch movements.

BRONZE MEDAL.

1226	Jas. E. Caldwell & Co.. Philadelphia,	Jewelry and Silver Ware.
1343	Isaac Bedicheimer, "	Jewels and Emblems in Gold, Silver and Enamel.
1855	Madame K. Schmidt, Philadelphia,	Hair Jewelry.

HONORABLE MENTION.

924	Young & McCully, Philadelphia,	Masonic Marks and Jewel Settings.

XIX.—Hardware, Cutlery, &c.

SILVER MEDAL.

36	Hoopes & Townsend, Philadelphia	Bolts, Washers and Wood Screws.
99	McCaffrey & Bro., Philadelphia.	Files, Rasps, &c.
199	Stuart, Peterson & Co., Philadelphia,	Enameled and Tinned Cast Iron, Hollow Ware.
225	Howard W. Shipley, Philadelphia,	Pocket Cutlery.
370	J. B. Shannon, "	Builders' Hardware.
438	Russell & Erwin, M'fg Co., Phila.	Builders' Bronze Hardware.
126	Andrew Rankin, "	Bronze Metal & Hand-plated Goods.
17	Yale Lock M'fg Co. Stamford, Conn.	Store-door, Cabinet Locks & Latches.
1085	Mallory, Wheeler & Co., Field & Hardie, Agents,	Mortise, Rim and Padlocks.
747	Wm. Baldwin, Philadelphia,	Steel Forging Hammers, Sledges, &c.
471	Henry Disston & Sons, "	Saws and Tools.
1147	Charles Parker, Meriden, Conn.	Bench Vise.
618	Enterprise Manuf. Co., Philadelphia,	Coffee Mills.
1507	" " " "	Spice and Drug Mills.
212	A. B. Shipley & Son, "	Fishing Tackle.
65	L. Herder & Son, "	Shears and Scissors.

BRONZE MEDAL.

667	Alex. Krumbhaar, Philadelphia,	Files.
421	Washburn & Moen M'fg Co., N. Y. City,	Manufacturers' Wire.
422	White & Sansom, Philadelphia,	Table Cutlery.
735	Barrows, Savery & Co., Philadelphia,	Tailors'. Hatters' and Sad Irons.
1355	Wm. Ruoff. Philadelphia,	Patent Jackscrew.
47	Stevens Pat. Parallel Vise Co., New York,	Parallel Vises.
503	Hopkins & Dickerson, Field & Hardie, Ag'ts.	Bronze Door Knobs.
758	John P Verree & Co., Philadelphia, A. B Shipley & Son, Agents,	Hatchets.
453	Knickerbocker Ice Co , Philadelphia.	Ice Tools.

HONORABLE MENTION.

148	Hillebrand & Wolf, Philadelphia,	Trunk Locks and Padlocks.
872	E. S. Wells, "	Spoon-pointed Wood Screw.
1350	Philada. Tool Co., "	Davis' Patent Duplex Wrench.
763	John Booth & Sons, "	Brace-bits and Screwdrivers.
203	Wm P. Walters' Sons, "	Mechanics' Tools.
1380	H. S. Tarr & Son, "	Excelsior Dry Level,
502	Field & Hardie, "	Window Pulley.
630	Baylis & Darby Manufac'g Co. Philada.	Wire Work.
772	Lloyd, Supplee & Walton, "	Bonney's Pat. Hollow Auger.
605	Heaton & Denckla, Agents Philadelphia, Union M'fg Co., New Britain Conn.	Plain and Fancy Door Butts.

XX.—Hats, Caps, and Furs.

BRONZE MEDAL.

544	F. K. Womrath,	Ladies Furs.

HONORABLE MENTION.

1006	W. H. Oakford, Philadelphia,	Hats.
810	Jno. A. Stambach & Co., Philadelphia.	Fancy Furs.

XXI.—House Building Materials, Tiles, and Terra Cotta Ware.

BRONZE MEDAL.

46	Wm, L. Wilson, Philadelphia,	Drain Pipe and Chimney Tops.
401	Fredk. Gossin, "	Garden Statuary and Vases.
97	Phila. Architectural Iron Co., Philad'a,	Galvanized Iron Work.
35	Austin & Obdyke, "	Corrugated Water Conductor.

HONORABLE MENTION.

196	Drury & Melluish, Philadelphia.	Plaster Ornaments.
1223	C. Burnham & Co., "	Gilroy's Weather Strips.
1138	McNeil, Irving & Rich, Elwood N. J.,	Pat. Waterproof Building Paper.
1210	Jos. E. Billings, Boston, Mass.,	Universal Angle Brick.
142	Geo. Hayes N. Y.	Hayes' Patent Skylight.
362	Wm. F. Scheible, Philadelphia.	Awnings and Decorations.

XXII.—Housekeeping Articles.

SILVER MEDAL.

145	C. G. Blatchley, Philadelphia,	Tingley's Patent Horizontal Ice Cream Freezer.
531	Wm. Wiler, "	Stair Rods.
347	John Gravenstine, "	Sideboard Refrigerator and Water Cooler Combined.

BRONZE MEDAL.

234	Chas. W. Packer, Philadelphia,	Ice Cream Freezer.
346	John Gravenstine, "	Refrigerator and Cooler Combined.
1197	Jeremiah Rohrer, Lancaster, Pa.,	"Iceberg" Refrigerator.
732	Barrows, Savery & Co., Philadelphia,	Refrigerator and Cooler Combined.
279	A. & R. O. Applegate, "	Centennial Ironing Table.
1100	E. S. Farson & Co., "	Schooley's Patent Self-Ventilating Refrigerator.
843	L. B. Justice, "	Seamen's Ice Cream Freezer.

HONORABLE MENTION.

1518	F. G. Ford, Philadelphia,	Pat. Coal Hod or Flour Pail and Sifter Combined.
578	Wilson, Wood & Co., Wilmington, Del.,	Crockery Well Water Cooler.
1010	F. Lawrence, Philadelphia,	Revolving Flower Bracket.
435	Orum & Millor, "	Gas Bracket Match Safe.
333	Amanda S. Sherwood, Philadelphia,	Bixler's Fountain Griddle Greaser.
934	Thos. Mills & Bro., "	Steam Engine and Ice Cream Freezer Combined.
1361	John McConn, "	Non-Explosive Steam Coffee Pot.
1388	T. B. Hagner, "	American Automatic Filterers.

XXIII.—India-Rubber Goods.

SILVER MEDAL.

1409	A. K. Young & Conant Manufacturing Co., Boston, Mass.,	Gossamer Waterproof Garments.

HONORABLE MENTION.

1095	New York Belting and Packing Co., D. P. Dieterich Agent, Philadelphia.	Rubber Belting.
216	Boston Elastic Fabric Co., Potter & Hoffman, Agents, Philadelphia,	Rubber Fire Hose.

XXIV.—Iron and Steel.

SILVER MEDAL.

716	Alan Wood & Co., Philadelphia,	Patent Planished Sheet Iron.
1324	Am. Tubular Iron and Steel Asso., Phila.,	Wheeler's Tubular Wrought Iron.
606	Midvale Steel Works, Nicetown, Pa.,	Crucible Cast Steel.
607	" " " "	Steel made by Siemen's Martin process.
27	Phila. Galvanizing Co., Philadelphia,	Galvanized Iron.
1367	Pennsylvania Combined Iron and Steel Association, Philadelphia.	Wheeler's Combined Iron and Steel for Railroad and Merchant Bars.
822	Susquehanna Iron Co., Columbia, Pa.,	Merchant Bar Iron.
956	Fitzgerald, Flagg & Co., Philadelphia,	Cast Steel Castings.

BRONZE MEDAL.

407	Phila. Hydraulic Works, "	McHaffie Direct Steel Castings.
312	Hanson & Kirk, "	Cemetery-Lot Enclosings.
215	Union Iron Co., Buffalo, N. Y., Potter & Hoffman, Agents, Philadelphia,	Long Iron Beams.
355	Miller, Barr & Parkin, Pittsburg, Pa.,	Cast Steel.
1303	Goodell & Waters, Philadelphia,	Iron Castings.

HONORABLE MENTION.

1136	Malin Bro's. Philadelphia,	Pig Iron.
1330	Edw'd J. Etting, "	Allentown Iron Co.'s Pig Iron.
337	Chas. H. Kellogg, " Potter & Hoffman, Agents,	Wrought Iron Column.

XXV.—Ladies' Fancy Goods.

SILVER MEDAL.

91	Birge & Berg, Philadelphia,	Artificial Flowers.
441	M. Shoemaker & Co., Philadelphia,	Children's Clothing.
468	Ladies' Depositary, "	Fancy and Useful Articles.
1456	Mrs. M. E. B. Wynne, New York,	Fancy Stitching on Shoes.
1464	Miss Maggie M. Doran, Philadelphia,	Glove Making.

BRONZE MEDAL.

380	Mrs. E. Keyser, Philadelphia,	Children's Clothing.
1268	A. J. Iander, "	Afghan and Needlework.
1368	W. B. Moore, "	Tips and Tags for Lacings.

HONORABLE MENTION.

294	Wm. Brooks, Philadelphia,	Bonnets.
373	David Wood, "	Infant's Clothing.
1281	Wheeler & Wilson Mfg. Co., Philadelphia,	Samples of Stitching.

XXVI.—Gas Fixtures.

SILVER MEDAL.

100	Cornelius & Sons, Philadelphia,	Gas Fixtures.
501	M. B. Dyott & Son, "	Champion Street Lamps.

BRONZE MEDAL.

83	Baker, Arnold & Co., Philadelphia,	Gas Fixtures.
777	Wilhelm & Neuman, "	Street Lamps.
1018	August Wilhelm, "	Ceiling Reflector.

HONORABLE MENTION.

109	American Reflector Co., Philadelphia,	Goetz' Day and Gas Light Reflectors.

XXVII.—Leather and Morocco.

SILVER MEDAL.

1445	F. Braun, Philadelphia,	Calf Skins.

BRONZE MEDAL.

191	Eckfeldt & Richie, Philadelphia,	Oak-Tanned Butts for Hose & Belting.

HONORABLE MENTION.

2[illegible]1	A. McKnight & Co., Philadelphia,	Waterproof Leather.
276	Ed'd Spaulding, Boston, Mass.,	Hemlock-Tanned Sole Leather.
434	Deitrich & Whittington, Philadelphia,	Meyer's Pat. Marbled Sheep Skins.
764	C. B. Williams' Sons, "	Oak-Tanned Sole Leather.

XXVIII.—Marble, Stone, etc.

BRONZE MEDAL.

396	Adam Steinmetz, Philadelphia,	Colored American Marble Mantels.
1168	Wm. R. Hanson & Son, "	Lake Champlain Colored Marbles.
244	Chas. Williams, "	Marbleized Slate Mantels.
303	Wilson & Miller, "	" " "
321	Hayes, Coulter & Co., "	" " "
40	J. B. Kimes & Co., "	" " "
677	Thompson & Harper, "	" " "
130	J. E. Mitchell,	Collection of Grindstones, Oilstones, Curriers' Blocks and French Burr Millstones.

XXIX.-1.—Generators of Power.

SILVER MEDAL.

853	Harrison Boiler Works, Philadelphia.	Harrison's Sectional Boiler.

BRONZE MEDAL.

710	Steam Generator Mf'g Co., Philadelphia.	The Wiegand Sectional Safety Steam Generator.
690	Wm. J. Connery, "	Connery's Concave Caulking.
1084	Wm. T. Bates, Conshohocken, Pa.	Feed Water Heater and Filter.
287	Henry Snyder & Co., Philadelphia,	Shapley Steam-Engine, Portable.

HONORABLE MENTION.

627	Norris Iron Co., Norristown, Pa.	Norris Iron Co.'s Improvements on Rogers & Black's Boilers.
511	Waters' Pat. Heater Co., W. Meriden, Conn.	Waters' Pat. Feed Water Heater.

XXIX–2.—Motors other than Water-Wheels.

BRONZE MEDAL.

101	Robert Wetherill, Chester, Pa.,	Corliss Steam-Engine.
158	Andrew Watson, Philadelphia,	Upright Steam-Engine.
389	Jacob Naylor, "	Horizontal Steam-Engine.
457	Wilbraham & Bro., "	Horizontal Steam-Engine.

HONORABLE MENTION.

495	Shive Governor Co., Bethlehem, Pa.,	Shive Steam-Engine Governor.
553	Jacob Naylor, Philadelphia,	Balance Slide-Valve.
390	Jacob Naylor, "	Vertical Steam-Engines, 6 in., 8 in., 10 in. and 12 in. Cylinders.
636	Jenkins & Lee, "	Marine Governors.
551	Richards & Pike, "	Barr's Eliptic Steam Trap.
392	J. T. Mecutchen, "	Patent Eccentric Hook.

XXIX–3.—Machinery of Transmission.

SILVER MEDAL.

12	Alexander Bros., Philadelphia,	Leather Belting.
800	James Eccles, "	Model of Patent Pivot Centre for Drawbridge.
153	T. J. Rorer, "	Combination Union Belt.

BRONZE MEDAL.

177	Geo. V. Cresson, Philadelphia,	Internal Clamp Coupling for Shaft'g.
183	Sellers Bros., "	Main Driving Belt. J. B. Hoyt & Co., M'f'rs, New York.
1439	Pusey, Jones & Co., Wilmington,	Expanding Pulleys.
1440	" " " "	Wire Guide.

HONORABLE MENTION.

170	Murray Bacon, Philadelphia,	Rotary Circulating Fan.
141	Geo. V. Cresson, "	Shafting Hangers and Pulleys.
306	Wright & Smith, Machine W'ks, Newark, New Jersey,	Variable Speed Shafting.
574	James F. Tygh, Philadelphia,	Cigar Shield, Self Pressing.
514	Wm. M. Smith, Philadelphia.	Device for Driving Sewing Machines with Variable Speed.

XXIX–4.—Machinery of Transportation.

SILVER MEDAL.

7	The Wharton R. R. Switch Co., Phila.,	Wharton's Safety Railroad Switch.
648	*B. Tatham & J. W. Brittin, New York City,	Safety Catch for Elevators.

BRONZE MEDAL.

629	Geo. J. Woodruff, Norristown Pa.,	Model of Railroad Switch.
319	Nichols, Pickering & Co., Philadelphia,	Elliptic, Nest, Spiral and Volute Springs.
586	Stokes & Parrish, Philadelphia,	Elevator Winding Engine.
774	J. G. Brill & Co., "	Street Car Starter.
1230	Sellers Bros., "	Wrought Iron Bridge Railing.
583	C. W. Hunt, New York City,	Automatic Railway.
584	" " " "	Automatic Elevator.

* Referred to Committee of Science and the Arts. With a recommendation for the higher awards of the Institute.

HONORABLE MENTION.

6	Wm. Wharton, Jr., Philadelphia,	Rail Curving Machine.
9	The Wharton R. R. Switch Co., Phila.,	Steel Railroad Frog.
260	Thos. McBride, Philadelphia,	Hydraulic Car Brake.
1272	J. Singer & R. Mench, Harrisburg, Pa.,	Singer's Pat. Autom'ic Car Coupler.
1146	C. D. Alexander, Philadelphia,	McConnell's Automatic Car Coupler.
1271	Jacob Singer. Harrisburg, Pa.,	McAllister's Imp'd R. R. Brake Shoe.
382	Davis & Foulke, Philadelphia,	Fitts' American Road Steamer.

XXIX–5.—Pumps, Hydrants, etc.

BRONZE MEDAL.

106	R. D. Wood & Co., Philadelphia,	Mathew's Patent Fire Hydrant.
247	E. L. Richie, "	Slouthron's Bilge and Force Pump.
263	Rue Manufacturing Co. "	Little Giant Injector.

HONORABLE MENTION.

693	R. T. H. Stileman, Philadelphia,	Stop Cocks and Valves.
113	Cooper, Jones & Cadbury, "	Excelsior Suction and Force Pump.
632	J. H. Billington & Co., "	Putnam's People's Pump.
967	F. B. Colton, "	Prall's Pat. Aquameter Steam Pump.
446	Ferrell & Jones, "	Steam Pump.
1161	*Thos. M. Shank,	Water Meter.

XXIX–6.—Machine Tools.

SILVER MEDAL.

1513	Northampton Emery Wheel Co., Leeds, Mass., W. P. Walters' Sons, Agents,	Stove Plate Emery Wheel Grinding Machine.
105	Adam Neukumet. Philadelphia,	Keystone Crucible Machine.
129	J. Henry Mitchell, Philadelphia,	Iron Boxes & Grindstone Fixtures.
363	Oberlin Smith & Bro., Bridgeton, N. J.	Can Makers, Presses and Dies.
444	Thorne, De Haven & Co., Philadelphia,	Portable Drilling Machine.
448	Kiehner & Odenatt, "	Valve Seat & Metal-planing Machine.
449	C. Van Haagen & Co., "	Rotary Shaper.
533	Packer & Bates, "	Machine for Oval & Circular Cutting.
912	Henry Snyder & Co., "	Ames Engine Lathe.
1082	E. & A. Betts, Wilmington, Del.	Reder's Pat. Adjustment for Lathe Tool-posts.
217	P. H. & T. N. Root; Potter & Hoffman, Agents, Philadelphia,	Portable Forge.
458	T. Wilbraham & Bros., Philadelphia,	Baker's Pressure Blower.
1127	John L. Mason, "	Tire Shrinker.
21	Pliny E. Chase, Newark N. J.	Foot Back Geared Slide Lathes.
169	Murray Bacon, Philadelphia,	Hand Lathes.
1233	The Tanite Co., Stroudsburg, Pa.	Emery Wheel Milling Machine.
1494	D. P Dieterich, Philadelphia,	Vulcanite Emery Wheels.
1481	C. Van Haagen & Co., Philadelphia,	Twist Drill Grinding Machine.
761	Ferris & Miles, "	Axle Lathe.

BRONZE MEDAL.

75	Keystone Portable Forge Co., Philada.	Baxter Portable Forges.
98	Northampton Emery Wheel Co., Leeds, Mass., W. P. Walters' Sons, Agents,	Emery Wheels.
345	John Bird, Philadelphia,	Press for moulding Glassware.
575	James F. Tygh, Philadelphia,	Tobacco Strip'g & Booking Machine.

*Referred to Committee on Sciences and the Arts for Examination.

BRONZE MEDAL.

1183	Lucien B. Flanders, Philadelphia,	Pat. Portable Cylinder Boring Machine.
968	Charles Crossley, Philadelphia,	Patent Mill Picks.
1024	Allison & Bannan, Port Carbon, Pa.	Allison's Patent Boring Machine.
1237	Isaac H. Shearman, Philadelphia,	Johnson's Lathe Chuck.
1192	T. R. Evans, "	Indexical Revolving Boot and Shoe-tree Stretcher.
1239	Hill, Clark & Co., Boston, Mass.	No. 3 Brainerd Miller.
1295	W. D. Chase, M'fg Co., New York.	Chase's Pipe Cutting Machine.
1311	Keystone Portable Forge Co. Philada.	Grimes' Pressure Blower.

HONORABLE MENTION.

228	Lehigh Valley Emery Wheel Co., Weissport, Pa.	Butterfields Emery Wheels & Grinder.
1514	Chas. M. Chriskey, Philadelphia,	Portable Forges.
1047	George Richards, "	Twist Drill Grinding Machine.
1238	R. L. Howard & Son, Buffalo, N. Y.	6-inch Schlinker Bolt Cutter.
1241	Wood Light Machine Co., Worcester, Mass.	No. 1. Bolt Cutter.
1240	Hill, Clark & Co., Boston, Mass.	Index Miller.
1498	The Tanite Co., Stroudsbury, Pa.,	Emery Wheels,
1256	C. J. Gardner, Philadelphia,	Saw Grinding Machine. (Model.)
424, 425, 426	E. & A. Betts, Wilmington, Del.,	Display of Machine Tools.

XXIX–7.—Wood-Working Machinery.

SILVER MEDAL.

540	D. J. Lattimore, Philadelphia,	McClelland's Planing Mach. Duster.
593	Goodell, Braun & Waters, Philadelphia,	Endless Bed, Double Surfacer and Matcher.
594	" " "	Heavy Bar Mortiser and Borer.
1490	Power, Tainter & Co., "	Re-Sawing Machine.

BRONZE MEDAL.

300	Trump Brothers, Wilmington, Del.	Fleetwood Scroll Saw.
307	Power, Tainter & Co, Philadelphia,	Woodward Double Surfacing Floor-Board Planing Machine.

HONORABLE MENTION.

494	R. McChesney, Ilion, N. Y.	Truss Arm Scroll Saw.
1054	Walker Bros., Minneapolis, Minn.	Scroll Saw.
1145	J. H. Blaisdell & Co., Philadelphia,	Sash Boring and Grooving Machine.
1436	James M. Seymour, Newark, N. J.	Sash Dovetailing Machine.
1491	Power, Tainter & Co., Philadelphia,	Combined Sash Sticking and Moulding Machine.

XXIX–8—Textile Machinery.

SILVER MEDAL.

41	H. W. Butterworth & Sons, Philadelphia,	Warp and Cloth Drying Machine.
1397	Thos. Wood, Philadelphia,	3-Box Power Loom.
545	Dienelt & Eisenhardt, Philadelphia,	W. V. Gee's Pat. P'wr Carpet Loom.
1441	Pusey, Jones & Co,, Wilmington, Del.	Rag Cutter.
180	Thomas Wood, Philadelphia,	Single Box Power Loom.

BRONZE MEDAL.

826	Wm. McArthur & Co., Philadelphia,	McArthur's Patent Steam Feather Renovator.

HONORABLE MENTION.

1398	Thomas Wood, Philadelphia.	Winding Machine.
827	W. McArthur & Co., Philadelphia.	Steam & Hot Air Carpet Cleaning Machine.

XXIX-9.—Sewing Machines.

SILVER MEDAL.

28	Cutlan Shoe S M. Co., Philadelphia,	Cutlan Shoe Machine.
324	George C. Walters, Philadelphia,	Wet Skin Sewing Machine.
118	Rex & Bockius, "	Goodes Sewing Machine.

BRONZE MEDAL.

418	A. B. Felt & Co., Philadelphia,	Vertical Feed applied to the Davis Sewing Machine.
313	Cyrus S. Cushman, "	Sewing Machine Attachment.
397	John Mundell & Co., "	Machine for Screwing Soles on Boots and Shoes.
1489	A. C. McKnight, Philadelphia, for Cable Screw Co., Boston, Mass.	American Cable Screw Wire Machine for Boots and Shoes.

HONORABLE MENTION.

1086	Jos. J. West, New York,	Duplex Braiding and Embroidering Attachment.
437	Adjustable Table Co., Philadelphia,	Adjustable S. M. Table.
1342	J. Thomas Jones, Ilion, N. Y.,	"Eureka." The Remington Anatomical Treadle for Sewing Machines.

XXIX-10.—Laundry Machinery.

BRONZE MEDAL.

251	American Machine Co., Philadelphia,	Crown Clothes Wringer.
537	James Bing, Philadelphia,	R. A. Stratton's Mangle or Calender.
368	R. H. Farley "	Champion Steam Washer.

HONORABLE MENTION.

1202	J. D. Brick, Philadelphia,	Electric Washing Machine.

XXIX.-11.—Paper Machinery.

SILVER MEDAL.

195	Brown & Carver, Philadelphia,	Paper Cutting Machine.
1048	Brown & Carver, "	Hand Paper Cutter.
384	R. Mohler, "	Fourdrinier Wire Cloth.
1228	Sellers Brothers, "	Whitehead's Dandy Roll.
1232	Sellers Brothers, "	Paper Maker's Cylinder.
427	Nelson Gavit, "	Pat. Cone Pully Paper Cutter.
50	*Chambers Brothers, "	Fast Rotary News Folder.
51	* " " "	16 Page Folder and Paster.
52	* " " "	Adjustable 8 vo. and 12 mo. Book Folder.
406	*J. Morton Poole & Co., Wilmington, Del.,	Machine Calender Rolls.

BRONZE MEDAL.

11	Charles J. Cohen, Philadelphia, for Allen's Manufacturing Co. Norwich, Conn,	Allen's Machine for Gumming and Folding Envelopes.
298	R. S. Menamin, Philadelphia,	Heston's Label Cutter.

HONORABLE MENTION.

171	Wm. H. Burkhardt & Co., Philadelphia,	Cedar Ship Tank.
172	George J. Burkhardt & Co., "	Square and Round Cedar Tank.
480	Sellers Brothers, "	Paper Makers Fourdrinier Wire Cloth.
1164	Nelson Gavit, Philadelphia,	Paper Testing Machine.

* All of Chambers 'Brothers & Co's Machines are referred to the Committee of Science and the Arts for still higher awards. J. Morton Poole & Co., also referred to the Committee of Science and the Arts for still higher awards.

XXIX.—12.—Rope Machinery.

No Exhibits.

XXIX.—13.—Sugar Machinery and Chemical Appliances.

SILVER MEDAL.

162	Henry G. Morris, Philadelphia,	Improvements on D. M. Weston's Centrifugal Machines.
484	Walker Brothers & Co., Philadelphia,	Lightning Mill.
1431	Greene & Platt, "	Improved Fire Extinguisher.
76	David Stewart, "	Cracker Machine.

BRONZE MEDAL.

1468	George J. Burkhardt & Co., Philadelphia,	Improved Scotch Mashing Machine.
930	Thos. Mills & Brother, "	Excelsior Candy Toy Machine.
932	Thos. Mills & Brother, "	Improved Cocoa Nut Grating M'chn.
933	Thos. Mills & Brother, "	Fruit Drop Machine.

HONORABLE MENTION.

488	Walker Brothers, Philadelphia,	Farm Mill.
342	Kreider, Zindgraft & Co., Philadelphia,	Thompson's 30 inch Patent Portable French Burr Grain Mill.
343	Kreider, Zindgraft & Co., Philadelphia,	Thompson's 24 inch Patent Paint Mill, with Mixer.
55	Baugh & Sons, Philadelphia,	E. P. Baugh's Patent Sectional Mills.
179	W. H. and S. A. Slocomb, Philadelphia,	Fruit Cleaner, Apple Parer and Corer combined.
1469	Geo. J. Burkhardt & Co., Philadelphia,	Grains Valves.
26	Phila. Fire Extinguishing Co. "	Gardner's Triumph Hook and Ladder Truck.
684	C. K. Bullock, Philadelphia,	Straub Portable Grain Mill.

XXIX–14.—Stone Machinery.

SILVER MEDAL,

417	Excelsior Brick and Stone Co. Philadel.	Gregg's Excelsior Brick Making Machine.
562	Penna. Diamond Drill Co., Pottsville, Pa.,	Diamond Pointed Steam Drill.

BRONZE MEDAL.

582	Samuel P. Miller & Son, Philadelphia,	Hand Brick Press.

HONORABLE MENTION.

53	Chambers Bros. & Co., Philadelphia.	Brick Machine.

XXIX–15.—Gas Machinery.

SILVER MEDAL.

1521	American Meter Co., Philadelphia.	Improved jet Photometers (conditional award.)

BRONZE MEDAL.

1143	American Meter Co., Philadelphia,	Hopper's Dry Gas Meter.
161	Henry G. Morris, "	Self-Sealing Retort Lids.

HONORABLE MENTION.

1511	Harris, Griffin & Co., Philadelphia,	Dry Gas Meter.
472	Collins & Curl, Philadelphia,	Lacy's Automatic Gas Saver.
916	Samuel H. Mervine, Jr., Philadelphia.	Gas Regulator and Four way Stop Cock.

XXIX–16.—Lubricating Oils and Engineering Supplies.

SILVER MEDAL.

466	John W. Tully, Philadelphia,	Paint Filler for Wood and Metal.

BRONZE MEDAL.

487	E. F. Houghton & Co., Philadelphia,	Cosmo-lubric Oil.
658	Morehouse, Rockafeller & Co., Philad'a,	Paraffine Oil.
657	Eclipse Lubricating Oil Co., Franklin, Pa ,	Tweddle's Improvements in Manufacturing Mineral Oil.
1321	Taber, Harbert & Co., Philadelphia,	Monument No. 1 Illuminating Oil.
1180	Wm. L. Elkins, "	Continental Burning Oil.
1178	" " "	Belmont Burning Oil.
1474	" " "	Head-Light Oil, 175 degrees.
564	Davis & Dubois, "	Combination Tallow Cup.
791	Wickersham & Bro., "	The Wickersham Oil Cup.

HONORABLE MENTION.

1339	Crew, Moore & Levick, Philadelphia,	General Display of Oils.
1378	Geo. J. Faller, "	Excelsior Sewing Machine Oil.
863	Shepherd & Lloyd, Philadelphia, Agents for Tubular Barrow and Truck Co., Jersey City, N. J.,	Tubular Iron Wheelbarrow,
290	Edw'd Brown, Philadelphia,	Revolution Indicator.
865	Chas. Parham. "	Fine Machine Screws.
786	B. E. Lehman, Bethlehem, Pa.,	Ross' Patent Gauge Cock.
1039	Jos. Heginbothom, Philadelphia,	Swann's Patent Safety Valve.
955	Geo. Sumner, "	Steam Regulating Valve.
419	Chapman Valve Mfg. Co., Boston, Mass.,	Chapman Valve.
977	E. Schmidt, Philadelphia.	Steam Guage.
1301	E. H. Ashcroft, Boston, Mass.	Pop Safety Valve, nickel seated.
1286	E. H. Ashcroft, " "	Self-Testing Steam Guage.

XXX.—Musical Instruments.

SILVER MEDAL.

769	Wm. F. Seefeldt, Philadelphia,	Quartette of Brass Instruments.

BRONZE MEDAL.

66	Schomacker Piano Mfg. Co., Philadelphia,	Square Piano, No. 10,391.
1314	A. B. Felt & Co., Philadelphia, for Horace Waters & Son, Mfrs., New York,	Cabinet (reed) Organ, No. 31,960.
641	Jno. Albert, Philadelphia,	Stringed Instruments.

HONORABLE MENTION.

236	Albert Schoenhut, Philadelphia.	Toy Piano and Mellophone.
778	Rosewig & Stoll, Philadelphia, for A. M. McPhail & Co., Mfrs., Boston,	Square Piano, No. 11,13C.
402	Prestien & Berwind, Philadelphia,	Square Piano, No. 702.
354	Albrecht & Co., "	Square Piano, No. 1265.

XXXI.—Paints, Colors, Varnishes, Etc.

SILVER MEDAL.

965	Harrison Bro's & Co., Philadelphia,	Case of Colors.
1155	L. Martin & Co., "	Lamp Black.

BRONZE MEDAL.

612	Bihn & Co., Philadelphia,	Lamp Black.

XXXII.—*Paper Hangings.*

SILVER MEDAL.

555	A. Goth & Co., Bethlehem, Pa.,	Oil Painted Wall Papers & Frescoes.

BRONZE MEDAL.

451	Howell & Bro's, Philadelphia,	Excellence in Cheap Paper Hangings.
554	Nagle, Cooke & Ewing, Philadelphia,	Fine Selection of Wall Papers and artistic taste in hanging.

XXXIII.—*Philosophical, Optical and Mathematical Instruments.*

SILVER MEDAL.

1152	Becker & Son, N. Y.	Balances of precision.
1235	D. R. Walker, Phila.,	Fire Alarm Telegraph.
1251	J. W. Queen & Co., Philadelphia,	Edgerton's Self-condensing gas Cyl'r.
482	*Joseph Zentmayer, Philadelphia,	Microscopes and Objectives.
969	L. J. Marcy, Philadelphia,	Sciopticon.
849	Albert G. Busby, Philadelphia,	Stereopticon.
1273	T. A. Wilson & Co., Reading, Pa.,	Arundel Tinted Spectacles.
1051	Galvano Faradic Mfg. Co., New York,	Galvano-therapeutic Apparatus.
365	Wm. G. A. Bonwill, Philadelphia,	Electro Magnetic Mallet.
1255	Am. District Telegraph Co., New Yo k,	Improved Burglar Alarm Apparatus.
127	Heller & Brightly, Philadelphia,	Surveying Instruments.
829	W. J. Young & Sons, Philadelphia,	Coast Surveying Instruments.
1254	J. W. Queen & Co., Philadelphia.	Eaton's direct vision Spectroscope.

BRONZE MEDAL.

1058	Caspar W. Briggs, Philadelphia.	Magic Lantern Slides.
600	Thos. E. Cornish, "	House and Hotel Annunciators.
1204	Wm. J. Phillips, "	Printing Telegraph Instrument.
497	Shive Governor Co., Bethlehem, Pa.,	Shive's Watchman's Clock.

HONORABLE MENTION.

369	J. B. Shannon, Philadelphia,	Electro Mag. Annunciator for Hotels.
1206	Wm. Hockhauser, New York,	Morse Tel. Register, (self-starting.)

1174	I. P. Fries, Relay Switch Founder,	Referred to the Committee on Science and the Arts for Exam'n.
1284	E. T. Phillips' Pat. Cov'd Telegraph Wire,	
1410	Thurston's Testing Machine,	

XXXIV.—*Printing and Typography.*

SILVER MEDAL.

659	Jno. T. Graham & Co., Philadelphia,	Sholes & Glidden "Type Writer."
463	†Bullock Printing Press Co., Philada.,	Bullock Printing Press. Built by I. P. Morris & Co.
1094	E. Haughwout & Co., New York City,	Universal Printing Press.

BRONZE MEDAL.

1515	Taylor & Smith, Philadelphia,	Engraving and Printing Color Blocks
296	Robert S. Menamin, Philadelphia,	Lawrence's Pat. Brass Galley.
297	" " "	Bronstrup Lithographic Press.
1427	Mellor & Rittenhouse, "	Printer's Composition Rollers.
508	Rex & Bockius, "	Goodes' Gem Self-Ink. Print. Press.
176	Taylor & Smith, "	Photo-Lithographing.
372	Graf Bros., "	Imprv'd Autographic Transferable Ink.

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* Referred to the Committee on Science and the Arts, with the recommendation of the Elliot Cresson Gold Medal.

† Bullock Printing Press referred to Committee on Science and the Arts, with a recommendation of the Elliott Cresson Gold Medal.

HONORABLE MENTION.

295	Robt. S. Menamin, Philadelphia,	Printer's Chases.
329	Times Printing House, Philadelphia,	Specimen of Ornamental Letter Press Printing.
910	J. W. Daughaday & Co,, "	Small hand Printing Press.
1244	Rowley & Chew, "	Specimens of Wood Block Printing.
1450	Samuel P. Ferree, "	Specimens of Printing from 5 color Chromo type Cyl. Printing Presses.

XXXV.—Saddlery, Harness, Trunks and Whips.

SILVER MEDAL.

804	A. S. Jenks, Philadelphia,	Hines' Pat. Driving Bit.

HONORABLE MENTION.

566	Samuel R. Phillips, Philadelphia,	Harness (Double and Single.)
579	Watt & Kennedy, "	Trunks for Mercantile and other purposes.
102	S. H. Allen "	Fine Harness Ornaments,
1419	A. Lynch, "	Single and Double Harness.
1304	Boland Bros. "	Wood Hames.

XXXVI.—Safes, Bank Locks and Scales.

SILVER MEDAL.

317	Fairbanks & Ewing, Philadelphia,	Railroad Track Scales.
318	" " "	Hay or Coal Scales.
507	H. Troemner, "	Fine Balances.
650	Farrel, Herring & Co., "	Franklinite backing in Burglar Proof Safes.
1267	Riehlè Bros., "	Charging Scales.

BRONZE MEDAL.

1191	Moore & Mixsell, Philadelphia, for Brandon Manufacturing Co.,	Knife Edges in Howe R. R. Track Scales.
1264	Riehlè Bros., Philadelphia,	Window Beam showing Graduation & Figures on top in wagon scales
1186	Moore & Mixsell, "	New Arrangement for Drop Lever Scales.
905	W. Harmar Thomas,	Steam Safes.

HONORABLE MENTION.

200	Stewart, Marks, Ralph & Co., Phila.,	Packing and Weighing Machine.
1046	*Worrall Bank Lock Co., Philadelphia.,	Bank Lock.

XXXVII.—School Furniture and Educational Appliances.

SILVER MEDAL.

1087	J. A. Bancroft & Co., Philadelphia,	H. L. Andrews' Gothic School Desks and Seats.

HONORABLE MENTION.

409	John L. Smith, Philadelphia,	Map Case with Maps on Spr'g Rollers
107	John H. Harden, "	Adjustable Drawing Board Trestle.
151	I. Newton Pierce, "	Folding School Desk and Seat.

XXXVIII.—Soaps and Perfumery.

SILVER MEDAL.

954	McKeone, Van Haagen & Co., Philada.,	White Castile, Toilet and Laundry Soaps.
855	Arthur Fricke, "	Perfumery.

*Referred to the Committee on Science and the Arts for examination.

BRONZE MEDAL.

1124	Wm. Conway, Philadelphia,	Laundry Soaps.
80	J. S. & T. Elkinton, "	Clarified Soap.
30	S. C. Upham, "	Centennial Bouquet Perfume.
582	Wm. Wrigley, "	Mineral Scouring Soap.
711	W. H. Savournin, "	Lilly White Toilet Powder and Rouge.

HONORABLE MENTION.

49	Samuel Campbell, Philadelphia,	Extract of Hyacinthine.

XXXIX.—Steam Heaters, Heaters, Ranges, and Ventilators.

SILVER MEDAL.

1042	J. Reynolds & Sons, Philadelphia,	Wrought Iron Furnace for setting in brick work.
364	McCoy & Roberts, Philadelphia,	Cold Case Hot Air Portable Heater.
1214	T. S. Dixon & Sons, "	Low Down and Elevated Grates, and Fenders.

BRONZE MEDAL.

1041	J. Reynolds & Sons, Philadelphia,	Centennial Hot Air Furnace.
71	D. Mershon's Sons, "	Air Tight Russian Heater.
37	Jno. McConn, "	Steam Radiator.
88	W. H. Harrison & Bro., "	Low Down and Elevated Grates, and Fenders.
1224	C. Burnham & Co., "	Reflecting Gas Stove.
1316	C. Gefrorer, "	Gas Heating Apparatus.
293	Strow, Wile & Co., "	Black Lead Crucibles.
744	Frank Lawrence, "	Patent Tuyere and Cupola.
135	Morris & Haines,	Portable Heater.
243	Charles Williams,	Heaters, Portable & set in brick work

HONORABLE MENTION.

509	J. P. Hayes & Bro., Philadelphia,	Rotary Hot Blast Portable Heater.
274	Leibrandt & McDowell Co., Philadelphia,	Victor Cooking Stove.
1225	C. Burnham & Co., "	Gas Cooking Stove.
913	G. Morgan Eldridge, "	Automatic Stove Damper.
1516	Strow, Wile & Co., "	Sunnyside Stove Polish.
1395	Adam Newkumet, "	Keystone Stove Polish.
798	J. W. Middleton, "	Automatic Regulator.
56	Geo. R. Barker, "	Combined Heating and Ventilating Apparatus.
89	W. H. Harrison & Bros.,	Warm Air Furnaces.

XL.—Miscellaneous.

SILVER MEDAL.

694	*Henry R. Heyl, Philadelphia,	Patent Wire-Fastened Paper Boxes.
525	H. H. Peacock, "	Inlaid Jewel Caskets.
233	Geo. F. Kolb, "	Morocco and Velvet Jewel Cases.
154	C. F. Rumpp, "	Fancy Leather Goods.

BRONZE MEDAL.

68	N. M. Kerr & Co., Philadelphia,	Paper Boxes for Jewelry, etc.
558	Chas. Rumpp, "	Fancy Leather Goods.

HONORABLE MENTION.

1453	Thos. Musgrove & Co., Philadelphia,	Patent Paper Boxes.
348	Edw'd Wattis, Jr., "	Patent Pocket Flasks.
830	Jacob Hoffman & Son, "	Pearl Handles, Studs, and Buttons.

* Referred to Committee on Sciences and the Arts, with the recommendation of the award of the Scott's Legacy Medal and Premium.

Civil and Mechanical Engineering.

COMPOUND AND NON-COMPOUND ENGINES.*

By Chas. E. Emery, C. E.

Messrs. Editors:—The experiments with the "Bache" form part of an extended series of investigations with steam machinery of various kinds, made to ascertain the best means of securing economy of fuel. The experiments were commenced by the writer (then an Assistant Engineer in the U. S. Navy) in the year 1866, and were continued in connection with the Novelty Iron Works, New York, where a special apparatus was fitted up for the purpose. [The experiments were entirely independent of those the Government had in progress at the same time.] Among other results it was in due time developed that the compound engine furnished one of the best practical means of securing economy of fuel, but the proprietors of the Novelty Iron Works decided to close the establishment in the winter of '69-'70, and nothing further was done at the time.

The results then obtained showed with considerable accuracy the law of variation in the cost of the power due to the changes of the steam pressure and degree of expansion, with other matter of importance, which, coming to the attention of Capt. C. P. Patterson, then connected with, now Superintendent of the U. S. Coast Survey, so interested him that he made arrangements to provide the means required to complete the trials on the plan originally intended. The experimental machinery was in part purchased in the general sale at the Novelty Works, and after being reconstructed the experiments were in due time proceeded with, though the loss of the skilled workmen and facilities of the Novelty Works was severely felt and caused unexpected expenses and delay. Messrs. Hecker & Bro., the well-known millers, with characteristic public spirit rendered valuable assistance by providing a location for the machinery, with use of boilers, pumps, etc.

These experiments included a trial of nearly every possible change of arrangement and condition to which simple and compound engines could be put in relation to steam pressure, expansion, use of steam jackets, etc. Upon completing the principal computations it was found desirable to ascertain the nature of the change in result due to increasing the size of engines of the same general character. Other experiments with which I had been associated furnished part of the necessary data, but to still further complete the investigation, with the consent of the Superintendent of the Coast Survey practical experiments were made with the machinery of the U. S. Coast Survey

* Report of Experiments made with the Steam Machinery of the U. S. Coast Survey Steamer "Bache," under the general direction of Charles E. Emery, Consulting Engineer. (Published by permission of the Superintendent of the U. S Coast Survey.)

Steamers "Blake" and "Bache" corresponding to some of those with the experimental apparatus.

The pressure of professional duties has prevented me from promptly completing the arrangement and discussion of the many hundred experiments with the deductions due to the numerous changes of condition, but the results will as soon as possible be reported to the Superintendent of the Coast Survey and promptly published.

The information derived from the trials of the experimental machinery was utilized in some degree in designing the machinery for the U. S. Revenue Steamer "Rush," and it having been found expedient to put machinery of different kinds in the two sister vessels, the "Dexter" and "Dallas," there resulted therefrom the series of trials of said vessels by a Joint Board of Naval and Revenue Marine Officers under the general direction of Chief Engineer Loring, U. S. N., and myself. C. E. E.

New York, November, 1874.

DESCRIPTION OF THE MACHINERY.

The engine and hull of the "Bache" were built in the year 1870, by Messrs. Pusey, Jones & Co., of Wilmington, Delaware. The engine was designed by Mr. Emery, the Consulting Engineer, and is of the steepled compound type, the larger cylinder, which is steam jacketed, being supported vertically upon frames as in ordinary vertical engines. The smaller cylinder, which is not steam jacketed, is supported above the other by four side columns. The pistons are attached to the same piston rod. Suitable pipes and valves are provided, so that the live steam can be supplied to the larger cylinder and excluded from the smaller, the former then working as a single engine. Ordinarily, when operating as a compound engine, the steam from upper cylinder passes to the chest of the lower through a large pipe, no pains having been taken to reduce the intermediate space, as the distribution of power between the two cylinders can easily be regulated by the adjustable cut-off on the larger.

Steam is distributed to each cylinder by a short slide valve at each end, and for both cylinders there are independently adjustable cut-off plates on the back of the main valves. The valve faces of the upper cylinder are carried out so that the valves of both cylinders are operated by continuous stems, but the ports, which lead directly out from the clearances, are shorter than usual for the upper cylinder and of the least possible length in the lower cylinder. The engine is provided with a surface condenser. The air pump is operated through the usual levers from the main crosshead. The circulating

pump is of the centrifugal pattern, operated by a small independent engine, directly connected.

The boiler is of the Scotch return tubular type, and of sufficient strength for a steam pressure of one hundred pounds, according to U. S. laws, though ordinarily worked at eighty pounds pressure. It is provided with a steam chimney arranged above the front connection in the usual manner and connected to the boiler by a large tube.

The following are the principal dimensions of the machinery :

ENGINE.

	High Pressure.	Low Pressure
Diameter of Cylinders, inches, ...	15·98	25·
Diameter of Piston Rods, "	2·5	3·625
Stroke of Pistons, "	24·00	24·00
Size of Cylinder Ports, "	$9\times1\frac{1}{2}$	$18\times1\frac{1}{2}$
Ratio of Piston Displacement to Capacity of Clearance and Passages,	·0486	·0405
Comparative effective Capacities of the two Cylinders,	1·00 ·40987	2·4398 1·00
Ratio capacities of Cylinders to capacities of Intermediate Chambers and Passages	2·6272	1·0768

BOILER.

Diameter, ...	8 ft. 2 inches.
Length, ...	12 ft.
Inside diameter of Furnace Flues, . . .	34 inches.

Tubes, 90 in number, 9 ft. 9 inches long and 3 inches in diameter.

Grate Surface, ...	31·16 sq. ft.
Calorimeter or area through tubes for draft, .	3·78 "
Water Heating Surface, ...	950·10 "
Steam Heating Surface, ...	54·32 "
Ratio Grate Surface to Calorimeter, . . .	8·25 "
Ratio Heating to Grate Surface, . . .	30·50 "
Ratio Heating Surface to Calorimeter, . .	252·02 "
Ratio Calorimeter to Steam Space, (9 inches water above tubes,)	48·80 "

MANNER OF CONDUCTING THE EXPERIMENTS.

The trials were made with the vessel secured to the dock. A double tank of iron for measuring the water delivered from the surface

condenser was placed on the main deck in the gangway abreast of the engine, and a pipe with regulating cock in the same led from each compartment to a tank in the hold, from which the water was withdrawn by the engine feed pumps.

The water was delivered to the measuring tank directly by the air pump through a pipe with flexible termination, which could be directed into either compartment of tank. Each compartment held by calculation very nearly ten cubic feet, at the height of a central overflow partition, but the exact capacity was ascertained by weighing water into same of the average temperature of the feed.*

The measurement was made by filling one compartment until it overflowed into the other, which had been previously emptied; the supply was then changed to the latter, and when the surplus water in first had run off, that compartment was emptied, and cock on bottom of same closed in time to receive the overflow from the other, the operation being repeated alternately with each compartment.

To prevent the misplacing of the cocks the attendant gave notice when each compartment was nearly full, and when the water first broke over the partition a signal was given and the reading of engine counter was noted. A comparison of the differences of successive readings and constant attendance of two persons effectually prevented errors. On the next even minute after filling a tank the reading of engine counter was again taken, also the usual engine room data and the duration of experiments was fixed, so far as measurements were concerned, by the tank intervals and in respect to speed by the nearest time intervals.

By this plan the officer on watch had but one thing to do at a time; the principal calculations were left for office work; the experiment could be held to start and stop at such records as best showed the uniformity of condition desired for an experiment, and an interrupted run be accurately calculated up to the end of the tank interval immediately preceding the interruption.

Indicator Diagrams were taken every twenty minutes.

The water level in boiler was noted every time a tank was filled, but did not vary appreciably, as the condenser was quite tight and all leaks were of a trifling nature. The condensed water from jackets and intermediate chamber was collected and weighed in separate vessels,

*[An illustrated description of this tank will appear in the March number.—Ed.]

TABLE NO. 1, SHOWING THE RESULTS OF EXPERIMENTS WITH THE STEAM MACHINERY OF THE U S COAST SURVEY STEAMER "BACHE" AT BALTIMORE MD., IN MAY 1874 (FOR DIMENSIONS OF ENGINE AND BOILER SEE SEPARATE TABLE.)

No.		MANNER IN WHICH ENGINE WAS OPERATED		COMPOUND, WITHOUT USING STEAM JACKET, BUT DRAINING INTERMEDIATE CHAMBER						COMPOUND USING STEAM JACKET AND DRAINING INTERMEDIATE CHAMBER			
				H P Cyl	L P Cyl	H P Cyl	L P Cyl	H P Cyl	L P Cyl	H P Cyl	L P Cyl	H P Cyl	L P Cyl
1	Designation of Runs.	Number for reference		1		2		3		4		5	
2		Designation in log		8		7		6		5		4	
3	Time.	Date of experiment	1874	May 14		May 14.		May 14		May 12.		May 12	
4		Duration of experiment	hours	1 833		2 066		2 133		1 733		2 066	
5	Steam Cut-off and Expansion.	Average steam pressure in boiler	lbs	82 00		80 28		80 3125		81 375		80 333	
6		" cut-off in fractions of stroke	"	231	503	335	833	405	.779	103	820	229	8 31
7		Ratio of expansion		3.75	9.146	2 73	6 658	2 31	5 634	6 91	16 85	3 77	9 19
8	Vacuum and Barometer.	Average vacuum in condenser	inches	24 00		24 321		24 656		24 50		26 50	
9		" barometer	"	30 00		30 00		30 00		30 34		30 34	
10		" "	lbs	14 72		14 72		14 72		14 89		14 89	
11	Temperatures (Fahrenheit Scale)	Air. Average temperature engine room	degrees	96 00		96 00		96 00					
12		Air. " " fire room	"	84 00		86 33		86 33		81 375		80 00	
13		Water. " " sea water	"	62 00		62 00		62 00		60 00		60 00	
14		Water. " " discharge water.	"	87 00		92 00		91 33		82 00		79 00	
15		Water. " " hot well	"	98 00		100 00		105 33		110 00		104 00	
16	Revolutions	Total revolutions		4685		5912		6305		4042		5973	
17		Average " per hour		2555 91		2861 56		2955 93		2332 37		2891.00	
18		" " per minute		42 5985		47 6927		49 2655		38 873		48 185	
19	Indicator Diagrams	Average initial pressure in cylinder above atmosphere	lbs.	75 00	1 00	76 33	2 458	73 00	3 9	75 75	1.00	77 125	4 00
20		" total initial pressure in cylinder	"	89 72	15 72	91 05	17 178	87 72	18 62	90 64	15 89	92 015	18 89
21		" " terminal " "	"	24.345	7 72	30 47	9 18	32 32	10 02	20 76	10 39	27 39	11 89
22		" " cushion " "	"	28.595	5 532	29 52	5.97	32 42	6 02	26 39	6 77	30 03	1 89
23		" back pressure above atmosphere at beginning of stroke, small cylinder	"	2 800		4 333		5 280		1 700		5 000	
24		" total back pressure at half stroke, large cylinder.	"		3 360		3 414		3 328		3.650		3 050
25		" mean effective pressure.	"	34 801	8 153	43 514	9 7588	45 137	11 2756	24 484	10 341	35.39	13 014
26		Estimated friction pressure	"	.75	2 25	75	2 25	75	2 25	75	2.25	75	2 25
27	Power	Indicated horse-power (effective)		35 586	Both 55 928	40 85	Both 77 06	5332	Both 85 81	22 852	Both 46 4	40 87	Both 77 453
28		Net horse-power		34.82	Both 49 548	46 874	Both 69 812	52 434	Both 78 417	22 162	Both 40 59	40 005	Both 70 335
29	Water	Total weight of water received from hot well	lbs.	2391 00		3586 50		4184 25		1793 25		2088 75	
30		" " " " small chest and steam jacket.	"							132 25		235 25	
31		" " " " intermediate chamber.	"	30 00		79 00		62 00		95 75		91 00	
32		" " ascertained by measurement	"	2427 00		3665 50		4246 25		2021 25		3315 00	
33		Revolutions using same		4678		5906		6301		4047		5974	
34		Time using same	hours	1 826		2 0649		2 132		1 735		2 06631	
35		Hourly quantities. Water per hour as ascertained by measurement	lbs.	1329 13		1775 14		1991 67		1164 9		1604 31	
36		Hourly quantities. " " " " indicator diagrams	"	862 046	710 228	1207 6	948 82	1318 97	1059 45	673 673	857 824	1092 47	1220 36
37		Proportional quantities. Per centage of total water received from jacket and small chest						..		065		.070	
38		Proportional quantities. " " " " " " intermediate chamber		015		.0215		.014		047		030	
39		Proportional quantities. " " " " " " jacket, chest & "		015		0215		.014		112		100	
40		Proportional quantities. " " " " accounted for by indicator		.64857	.53435	68028	5345	66224	53194	57954	73809	68095	76067
41	Coal and Refuse	Total coal consumed	lbs.										
42		Average coal consumed per hour	"										
43		Coal consumed per square foot of grate per hour	"										
44		Percentage refuse from coal											
45		Combustible per hour	lbs.										
46	Performance of Engine	Water per indicated horse-power per hour by measurement	lbs	23 765		23 636		23 21		25 1082		20 7133	
47		" " " " " " indicator	"	15 413	12.699	15 671	12 312	15 371	12 346	14 553	18 532	11 104	15 756
48		" " net " " " measurement	"	26 8251		25 4271		25 3887		28 008		22 8095	
49	Performance of Engine and Boiler	Coal per indicated horse-power per hour	lbs	Calculated. 2 602		Calculated 2 522		Calculated 2 541		Calculated 2.749		Calculated 2 268	
50		" " net " " "	"										
51		Combustible per indicated horse-power per hour	"										
52		" " net " " "	"										
53	Performance of Boiler	No lbs water evap'd per lb. coal at observed pressure and temp.	lbs.										
54		Equivalent evaporation from atmospheric pressure and temp. 100°	"										
55		" " " " " 212°.	"										
56		No lbs. water evap'd per lb combustible at obs'v'd press. and temp.	"										
57		Equivalent evaporation from atmospheric pressure and temp. 100°	"										
58		" " " " " 212°	"										

No.	MANNER IN WHICH ENGINE WAS OPERATED	COMPOUND USING STEAM JACKET AND DRAINING INTERMEDIATE CHAMBER									
		H P Cyl	L P Cyl	H P Cyl	L P Cyl	H P Cyl	L P Cyl	H P Cyl	L P Cyl	H P Cyl	L P Cyl
1	Number for reference	6		7		8		9		10	
2	Designation in log	3		2		1st Evap		2d Evap		1	
3	Date of experiment	May 12		May 12		May 14		May 15		May 12	
4	Duration of experiment	1 933		1 983		7 066		17 233		2 00	
5	Average steam pressure in boiler	80 214		80 125		79 96		79 7		79 1	
6	" cut-off in fractions of stroke	318	831	396	803	398	822	4519	735	554	795
7	Ratio of expansion	2 86	6 975	2 35	5 732	2 34	5 707	2 09	5 007	1 74	4 24
8	Average vacuum in condenser	26 50		26 562		26 115		21 14		26 5	
9	" barometer	30 34		30 31		30 00		29 15		30 34	
10	" "	14 89		14.89		14 72		14 31		14 89	
11	Air. Average temperature engine room	80 00		76 66		83 70		90 00		78 00	
12	Air. " " fire room	78 00		75 33		83 80		85 06		76 66	
13	Water. " " sea water	60 00		60 00		61 90		64 66		60 00	
14	Water. " " discharge water.	78 50		79 66		90 20		92 53		80 66	
15	Water. " " hot well	103 00		102.00		106 60		125 26		117 33	
16	Total revolutions	6168		6705		23568.		49008		7268	
17	Average " per hour	3190 89		3381		3335 4		3217 22		3634	
18	" " per minute	53 1815		56 34		55 59		53 62		60 56	
19	Average initial pressure in cylinder above atmosphere	78 58	6 25	75 41	8 66	75 32	8 06	74 47	7 52	72 41	13 62
20	" total initial pressure in cylinder	93 47	21 14	90 30	23 55	90 04	23 08	88 78	22 83	87 30	28 51
21	" " terminal " "	33 72	12 93	38 30	14 23	36 95	14 11	34 40	12 93	47 16	16 89
22	" " cushion " "	36 29	4 89	35 05	4 29	40 94	5 02	37 69	6 26	42 80	4 89
23	" back pressure above atmosphere at beginning of stroke, small cylinder	7 700		9 266		10 066		9 200		14 733	
24	" total back pressure at half stroke, large cylinder.		3 264		3 328		3 360		3 253		3 317
25	" mean effective pressure.	42 34	14 484	42 938	15 68	45 3748	13 961	43.0608	11 908	45 33	19 44
26	Estimated friction pressure	75	2 25	75	2 25	75	2 25	75	2 25	75	2 25
27	Indicated horse-power (effective)	54 06	Both 90 181	58 086	Both 110 514	60 562	Both 106 028	55 4372	Both 102 263	65 911	Both 134 53
28	Net horse-power	53 104	Both 91 216	57 068	Both 102 069	59 5617	Both 97 7014	54 4716	Both 94 23	65 112	Both 125 75
29	Total weight of water received from hot well	3580 50		1184 25		15302 40		32278 50		5370 75	
30	" " " " small chest and steam jacket.	100 00		209		889 25		1977 00		232 00	
31	" " " " intermediate chamber.	98 00		70 50		249 00		599 25		77 00	
32	" " ascertained by measurement	3883 50		4463 75		16440 65		34854 75		5688 75	
33	Revolutions using same	6145		6706		23547		49001		7259	
34	Time using same	1 9258		1 954		7 059		15 230		1 9975	
35	Water per hour as ascertained by measurement	2016 56		2284 42		2329 03		2288 558		2847 9	
36	" " " " indicator diagrams	1485 23	1464 9	1778 07	1710 17	1681 00	1696 95	1518 76	1485 66	2323 1	2180 61
37	Per centage of total water received from jacket and small chest	051		046		.054		056		040	
38	" " " " " " intermediate chamber	025		.015		015		016		010	
39	" " " " " " jacket, chest & "	076		061		.069		072		050	
40	" " " " accounted for by indicator	73651	72643	77835	74888	.72176	72850	66363	64916	81573	76569
41	Total coal consumed							3818			
42	Average coal consumed per hour							250 64			
43	Coal consumed per square foot of grate per hour							8 84			
44	Percentage refuse from coal							19 8			
45	Combustible per hour							201 01			
46	Water per indicated horse-power per hour by measurement	20 332		20 3048		21 9661		22 3708		21 169	
47	" " " " " " indicator	14 974	14 769	15 851	15 251	15 854	16 004	14 852	11 528	17 268	16 209
48	" " net " " " measurement	22 1074		21 9989		23 8885		24 287		22 647	
49	Coal per indicated horse-power per hour	Calculated 2.227		Calculated 2 230		Calculated 2 405		Actual 2 151		Calculated 2 318	
50	" " net " " "							2 660			
51	Combustible per indicated horse-power per hour							1 966			
52	" " net " " "							2 133			
53	No lbs water evap'd per lb. coal at observed pressure and temp.							9 131			
54	Equivalent evaporation from atmospheric pressure and temp. 100°							9 206			
55	" " " " " 212°.							10 281			
56	No lbs. water evap'd per lb combustible at obs'v'd press. and temp.							11 385			
57	Equivalent evaporation from atmospheric pressure and temp. 100°							11 479			
58	" " " " " 212°							12 820			

No.	MANNER IN WHICH ENGINE WAS OPERATED	SINGLE ENGINE WITHOUT USING STEAM JACKET			SINGLE ENGINE USING STEAM JACKET			
		Large Cyl	Large Cyl	Large Cyl	Large Cyl	Large Cyl	Large Cyl	Large Cyl
1	Number for reference	11	12	13	14	15	16	17
2	Designation in log	14	13	[illegible]	11	[illegible]	[illegible]	[illegible]
3	Date of experiment	May 18	May 18	[illegible]	May 1[illegible]	May 1[illegible]	May 1[illegible]	[illegible]
4	Duration of experiment	1 80	1 983	[illegible]	2 10	[illegible]	[illegible]	[illegible]
5	Average steam pressure in boiler	81 00	79 625	[illegible]	80 8[illegible]	[illegible]	[illegible]	[illegible]
6	" cut-off in fractions of stroke	0475	096	[illegible]	082	[illegible]	[illegible]	[illegible]
7	Ratio of expansion	11 82	7 62	[illegible]	12 62	[illegible]	[illegible]	[illegible]
8	Average vacuum in condenser	24 00	23 78	[illegible]	24 00	25 285	25 52	[illegible]
9	" barometer	29 83	29 83	[illegible]	29 83	29 83	29 83	[illegible]
10	" "	14 64	14 64	14 64	14 64	14 64	14 64	[illegible]
11	Air. Average temperature engine room	86 3	86 75	[illegible]	85 00	84 66	[illegible]	[illegible]
12	Air. " " fire room	84 66	84 00	[illegible]	81 00	[illegible]	74 75	[illegible]
13	Water. " " sea water	66 00	66 00	[illegible]	66 00	[illegible]	[illegible]	[illegible]
14	Water. " " discharge water.	96 66	94 25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	Water. " " hot well	133 66	131 50	[illegible]	121 33	[illegible]	[illegible]	[illegible]
16	Total revolutions	4025	5345	5[illegible]	[illegible]	4671	[illegible]	[illegible]
17	Average " per hour	2236 11	2695 41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	" " per minute	37 2685	44 923	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	Average initial pressure in cylinder above atmosphere	74 3	76 1	[illegible]	74 16	[illegible]	[illegible]	[illegible]
20	" total initial pressure in cylinder	88 94	90 74	[illegible]	88 81	90 14	90 74	[illegible]
21	" " terminal " "	10 74	12 31	[illegible]	10 56	[illegible]	[illegible]	[illegible]
22	" " cushion " "	8 84	8 64	[illegible]	7 84	7 64	[illegible]	[illegible]
23	" back pressure above atmosphere at beginning of stroke, small cylinder							
24	" total back pressure at half stroke, large cylinder.	4 560	4 400	[illegible]	2 960	2 774	[illegible]	[illegible]
25	" mean effective pressure.	21 643	27 273	[illegible]	23 449	27 54	[illegible]	[illegible]
26	Estimated friction pressure	2 25	2 25	[illegible]	2 25	2 25	2 25	2 25
27	Indicated horse-power (effective)	47 24	71 75	[illegible]	54 838	74 618	[illegible]	66 74
28	Net horse-power	42 329	65 83	[illegible]	49 574	[illegible]	[illegible]	[illegible]
29	Total weight of water received from hot well	2088 75	4184 25	47[illegible]	2088 75	2088.75	5370 75	4184.25
30	" " " " small chest and steam jacket.				126 25	57 00	127 00	[illegible]
31	" " " " intermediate chamber.	7 00	2 00	[illegible]	14 0	8 30	[illegible]	[illegible]
32	" " ascertained by measurement	2095 75	4186 25	47[illegible]	3129 0	[illegible]	[illegible]	[illegible]
33	Revolutions using same	4035	5314	57[illegible]	5041 0	3831	[illegible]	[illegible]
34	Time using same	1 808	1 971	[illegible]	2 1046	[illegible]	2 142	[illegible]
35	Water per hour as ascertained by measurement	1656 04	2125 0	23[illegible]	1486 74	1797 4	[illegible]	[illegible]
36	" " " " indicator diagrams	993 364	1179 22	15[illegible]	[illegible]	1162 25	[illegible]	[illegible]
37	Per centage of total water received from jacket and small chest				0405	018	022	.015
38	" " " " " " intermediate chamber	002	.0005	002	004	0027	[illegible]	[illegible]
39	" " " " " " jacket, chest & "	002	0005	002	0445	0207	028	[illegible]
40	" " " " accounted for by indicator	59951	55492	[illegible]	[illegible]	64663	[illegible]	70668
41	Total coal consumed							
42	Average coal consumed per hour							
43	Coal consumed per square foot of grate per hour							
44	Percentage refuse from coal							
45	Combustible per hour							
46	Water per indicated horse-power per hour by measurement	35 075	29 616	[illegible]	27 118	24 088	[illegible]	[illegible]
47	" " " " " " indicator	21 028	17 755	[illegible]	16 418	15 576	[illegible]	[illegible]
48	" " net " " " measurement	39 144	32 280	[illegible]	[illegible]	26 23	[illegible]	[illegible]
49	Coal per indicated horse-power per hour	Calculated. 3 841	Calculated 3 243	Calculated [illegible]	Calculated 2 969	Calculated 2.638	Calculated 2.535	Calculated [illegible]
50	" " net " " "							
51	Combustible per indicated horse-power per hour							
52	" " net " " "							
53	No lbs water evap'd per lb. coal at observed pressure and temp.							
54	Equivalent evaporation from atmospheric pressure and temp. 100°							
55	" " " " " 212°.							
56	No lbs. water evap'd per lb combustible at obs'v'd press. and temp.							
57	Equivalent evaporation from atmospheric pressure and temp. 100°							
58	" " " " " 212°							

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and emptied into the tank from which the boiler was at the time being fed.

One experiment was made of sufficient length to determine accurately the evaporation of the boiler; and it having been shown that the water measurement was substantially the same from hour to hour when the conditions remained uniform, the opportunity was embraced to try a number of experiments of short duration showing the results under varied conditions, using the water measurement only. Previous to the evaporation trial, a quantity of coal was, in the presence of an officer, measured into a distinct portion of the coal bunkers, and the remainder of the bunkers boarded up. From this measured quantity the coal was taken as required for the fires, and each bucket made to balance accurately a fixed weight on a scale. The weighing was done by a careful machinist who had no knowledge of the quantity originally measured.

In the first experiment tried in this way the two methods of determining the quantity did not agree, and the coal measurement was rejected. Upon repeating the experiment there was a very close agreement, so the weighed quantity was adopted as correct.

The coal used was anthracite of fair quality.

The results of these experiments are shown in the following table, which is in such form that little explanation will be necessary. See supplementary sheet.

It will be observed that the experiments are arranged by the degree of expansion, under four general titles, two referring to the engine when compounded, and two to experiments with large cylinder when used separately; trials being made in each case at different degrees of expansion with and without using the steam jackets on the large cylinder. All the experiments were made with an approximate steam pressure of 80 pounds, except the last.

The actual performances will be found in lines 46 to 58 inclusive. The previous lines showing the several observed and calculated quantities upon which the performances are based. The weights of water withdrawn from the jackets and intermediate chamber are separately set forth, also the percentage which these quantities form of the total water used. The water collected from jackets and intermediate chamber having been evaporated in the boiler is in all cases included in making up line 35, showing the total weight of water used per hour, upon which the cost of the power is based.

The quantities which will probably be found most convenient for comparison are those shown in line 46, viz.: the Actual Weight of Water used per Indicated Horse Power per Hour.

To Capt. C. P. Patterson,
Supt. U. S. Coast Survey,
New York, August, 1874.

CHAS. E. EMERY,
Consulting Engineer U. S. Coast Survey.

REMARKS ON THE EXPERIMENTS MADE WITH A SMALL NON-CONDENSING STEAM-ENGINE BY B. DONKIN & CO., LONDON, SHOWING THE RELATIVE ECONOMIC EFFICIENCY OF STEAM-JACKETING, AND OF USING STEAM WITH DIFFERENT MEASURES OF EXPANSION.

By Chief Engineer B. F. Isherwood, U. S. Navy.

[Continued from Vol. lxix, page 28.]

THE ECONOMY OF THE STEAM JACKET.

As in the case of using steam with different measures of expansion, so in that of using the steam-jacket, the economy, though always in favor of the steam-jacket, will be found to vary in quantity with the ratio of the mean total pressure to the back pressure, and with the absolute mean total pressure; but the economy is not affected by the measure of expansion used, provided the mean total pressure and the back pressure are constant. The greater the ratio of the mean total pressure to the back pressure, *ceteris paribus*, the greater the economy of the steam-jacket; and the less the absolute mean total pressure, *ceteris paribus*, the greater the economy of the steam-jacket. For example: In the case of using the steam with the measure of expansion due to cutting it off at $\frac{3}{8}$ of the stroke of the piston, columns A and B, we find, making the comparison for the cost of the total horse-power in pounds of feed-water consumed per hour that, when steam was in the jacket this cost was 34·083 pounds, and when steam was not in the jacket, 40·076 pounds, showing an economy of $\left(\frac{40·076 - 34·083 \times 100}{40·076}\right) = 14·95$ per centum in favor of the jacket,

assuming, for unity, the cost without the jacket. If, now, a similar comparison be made for the experiment in columns E and F, in which the same back pressure and nearly the same mean total pressure existed as in experiments A and B, but in which the measure of expansion used was that due to cutting off at $\frac{3}{8}$ of the stroke of the piston, we find the cost of the total horse-power, with steam in the jacket, to be 39·428 pounds of feed-water consumed per hour, and without steam in the jacket 46·016 pounds, showing an economy in favor of the jacket of $\left(\frac{46{\cdot}016 - 39{\cdot}428 \times 100}{46{\cdot}016}\right) = 14{\cdot}32$ per centum, or almost exactly the same as when with the same pressures the steam was cut off at $\frac{3}{8}$ of the stroke of the piston in experiments A and B. Hence, it appears that, *ceteris paribus*, the economy of the steam-jacket is not affected by the measure of expansion with which the steam is used.

In the case of experiments C and D, in which the steam was cut off at $\frac{3}{8}$ of the stroke of the piston as in experiments E and F, and in which the back pressure was the same, but in which the mean total pressure was greatly higher, making also the ratio of the mean total pressure to the back pressure much higher, the effect of this higher mean total pressure and its higher ratio to the back pressure becomes very apparent in the reduction of the economy of the steam jacket. Making the comparison for the cost of the total horse-power in pounds of feed-water consumed per hour, we find it when steam is in the jacket, to be 39·008 pounds, and when steam is not in the jacket, 43·039 pounds, showing an economy for the jacket of only $\left(\frac{43{\cdot}039 - 39{\cdot}008 \times 100}{43{\cdot}039}\right)$ $= 9{\cdot}04$ per centum, instead of 14·32 per centum, as in the case of experiments E and F, made with the same measure of expansion, but with different mean total pressure.

The amount of economy given by the steam-jacket, as determined for the total horse-power, is no indication of its amount for the net horse-power, that amount being sometimes greater and sometimes smaller for the net horse-power than for the total horse-power, according to the conditions of the case. For example: in experiments A and B the cost of the net horse-power in pounds of feed-water consumed per hour when steam was in the jacket was 60 632 pounds, and ween steam was not in the jacket, 78·128 pounds, showing an economy

of $\left(\frac{78{\cdot}128 - 60{\cdot}732 \times 100}{78{\cdot}128}\right) = 22{\cdot}27$ per centum for the jacket, instead of 14·95 per centum, as given when computed for the total horse-power.

Again, in the case of experiments C and D, the cost of the net horse-power, when steam was in the jacket, was 55·890 pounds of feed-water consumed per hour, and when steam was not in the jacket, 65·998 pounds, showing an economy of $\left(\frac{65{\cdot}998 - 55{\cdot}890 \times 100}{65{\cdot}998}\right) = 15{\cdot}32$ per centum for the jacket, instead of 9·04 per centum as given when computed for the total horse-power.

Finally, in the case of experiments E and F, the cost of the net horse-power when steam was in the jacket, was 81·527 pounds of feed-water consumed per hour, and when steam was not in the jacket, 91·133 pounds, showing an economy of $\left(\frac{91{\cdot}133 - 81{\cdot}527 \times 100}{91{\cdot}133}\right) = 10{\cdot}54$ per centum for the jacket, instead of 14·32 per centum, as given when computed for the total horse-power.

Of course, the commercial value of the steam-jacket, like the commercial values of the different measures of expansion, is that which is given for the net horse-power, and its amount depends entirely upon the conditions of the case, each problem requiring a particular solution.

THE QUANTITY OF STEAM CONDENSED IN THE JACKET TO FURNISH THE HEAT IMPARTED TO THE CYLINDER.

The purpose of the steam-jacket is to furnish heat to the cylinder, and thereby prevent the condensation of steam within the same. This heat can only be obtained by the condensation of steam in the jacket, and the experiments enable us to determine for the experimental conditions, the weight of steam thus condensed in the two cases of using the steam with measures of expansion due to cutting it of at $\frac{3}{8}$ and at $\frac{2}{3}$ of the stroke of the piston.

The experimental data, line 5, give 30 pounds for the weight of steam condensed per hour by external radiation from the steam-pipe and steam-jacket, when the engine was not in operation, but the jacket remained filled with steam of the boiler pressure, and this quantity was constant. The data also gives the weight of steam condensed per hour in the steam-jacket when filled with steam of the same boiler-

pressure, but with the engine in operation, line 6, consequently the subtraction of the former from the latter quantity gives the weight of steam condensed in the jacket to furnish the heat imparted to the cylinder and acting for the prevention of condensation, within the same.

During experiment A, when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, the quantity of heat imparted to the cylinder by the steam-jacket, was the quantity measured by the condensation per hour of (53·333—30·000 =) 23·333 pounds of steam of the boiler pressure; or, as the latent heat of the boiler-pressure (45 pounds per square inch above the atmosphere) is 908·418 units, there were imparted per hour to the cylinder by the jackets (23·333 × 908·418 =) 21196·420 units of heat.

During experiment C, when the steam was cut off at $\frac{5}{8}$ of the stroke of the piston, the quantity of heat imparted to the cylinder by the steam-jacket, was the quantity measured by the condensation per hour of (47·636 — 30·000 =) 17·636 pounds of steam of the boiler-pressure, or there were imparted per hour to the cylinder by the jacket (17·636 × 908·418 =) 16020.860 units of heat.

During experiment E, when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, the quantity of heat imparted to the cylinder by the steam-jacket, was the quantity measured by the condensation per hour of (47·000 — 30·000 =) 17·000 pounds of steam of the boiler-pressure, or there were imparted per hour to the cylinder by the jacket (17·000 × 908·418 =) 15443·106 units of heat.

The great efficiency of the steam-jacket in economizing the steam, will appear from the following considerations; taking, first, the data of experiment A, in which the steam is cut off at $\frac{3}{8}$ of the stroke of the piston. If, in that experiment we deduct from the weight of feed-water pumped into the boiler per hour, the weight of steam condensed per hour by external radiation, and divide the remainder by the total horse-powers developed by the engine, we shall obtain for the cost of the total horse-power $\left(\frac{361 \cdot 244 - 30 \cdot 000}{10 \cdot 599} =\right)$ 31·252 pounds of feed-water consumed per hour. Taking, now, the data of experiment B, and performing the same calculation, we obtain for the cost of the total horse-power $\left(\frac{354 \cdot 155 - 30 \cdot 000}{8 \cdot 837} =\right)$ 36·682 pounds of feed-water consumed per hour. The difference of 5·430 pounds in these two

cases is due entirely to the heat imparted by the jacket to the cylinder, and for the 10·599 total horse-powers developed by the engine during experiment A, would amount to ($10·599 \times 5.430 =$) 57·55257 pounds per hour, and as the total heat of the steam of the boiler pressure is 1203·0762 units, while the temperature of the back pressure is 216·33 degrees Fahrenheit, the units of heat in this quantity of steam would be ($986·7463 \times 57·55257 =$) 56789·785, and the waste of this quantity of heat in the cylinder by the condensation therein of the steam due to other causes than the production of the power, is prevented by the condensation of a sufficient quantity of steam in the jacket to furnish 21196·420 units of heat, as previously shown.

Again, in the case of experiment C, in which the steam is cut off at $\frac{2}{3}$ of the stroke of the piston, if we deduct from the weight of feed-water pumped into the boiler per hour, the weight of steam condensed per hour by external radiation, and divide the remainder by the total horse-powers developed by the engine, we shall obtain for the cost of the total horse-power $\left(\frac{562·145 - 30·000}{14·411} =\right)$ 36·926 pounds of feed-water consumed per hour. Taking, now, the data of experiment D, and performing the same calculation, we obtain for the cost of the total horse-power $\left(\frac{556·364 - 30·000}{12·927} =\right)$ 40·718 pounds of feed-water consumed per hour. The difference of 3·792 pounds in these two cases is due entirely to the heat imparted by the jacket to the cylinder, and for the 14·411 total horse-powers developed by the engine during experiment C would amount to ($14·411 \times 3·792 =$) 54·646512 pounds of feed-water consumed per hour, and as the total heat of the steam of the boiler pressure is 1203·0762 units, while the temperature of the back pressure is 216·33 degrees Fahr., the units of heat in this quantity of steam would be ($986·7463 \times 54·646512 =$) 53922·243; and the waste of this quantity of heat in the cylinder by the condensation therein of the steam due to other causes than the production of the power, is prevented by the condensation of a sufficient quantity of steam in the jacket to furnish 16020·860 units of heat, as previously shown.

Finally, in the case of experiment E, in which the steam is cut off at $\frac{2}{3}$ of the stroke of the piston, if we deduct from the weight of feed-water pumped into the boiler per hour, the weight of steam condensed per hour by external radiation, and divide the remainder by the total

horse-powers developed by the engine, we shall obtain for the cost of the total horse power $\left(\frac{334 \cdot 667 - 30 \cdot 000}{8 \cdot 488} =\right)$ 35·894 pounds of feed-water consumed per hour. Taking now the data of experiment F, and performing the same calculation, we obtain for the cost of the total horse-power $\left(\frac{419 \cdot 667 - 30 \cdot 000}{9 \cdot 120} =\right)$ 42·727 pounds of feed-water consumed per hour. The difference of 6·833 pounds in these two cases is due entirely to the heat imparted by the jacket to the cylinder, and for the 8·488 total horse-powers developed by the engine during experiment E, would amount to ($8 \cdot 488 \times 6 \cdot 833 =$) 57·998504 pounds of feed-water consumed per hour, and as the total heat of the steam of the boiler-pressure is 1203·0762 units, while the temperature of the back pressure is 216·33 degrees Fahr., the units of heat in this quantity of steam would be ($986 \cdot 7463 \times 57 \cdot 998504 =$) 57229·809; and the waste of this quantity of heat in the cylinder by the condensation therein of the steam due to other causes than the production of the power, is prevented by the condensation of a sufficient quantity of steam in the jacket to furnish 15443·106 units of heat, as previously shown. The steam-jacket in the case of experiment E, is more efficient than in experiment C, giving a greater economy, though in both cases the steam was cut off at $\frac{2}{3}$ of the stroke of the piston. The reason of this is that the less absolute mean total pressure in experiment F, produced by throttling, gave a much greater cylinder condensation to be acted on preventively by the steam-jacket.

The use of the steam-jacket when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, effected for every unit of heat imparted by the jacket to the cylinder, a saving within the latter of 2·679 units by the prevention of condensation.

The use of the steam-jacket when the steam was cut off at $\frac{2}{3}$ of the stroke of the piston, and the mean total pressure was about the same as when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, effected for every unit of heat imparted by the jacket to the cylinder, a saving within the latter of 3·706 units by the prevention of condensation.

The use of the steam-jacket when the steam was cut off at $\frac{2}{3}$ of the stroke of the piston, and the mean total pressure was about fifty per centum greater than in the preceding two cases, effected for every unit of heat imparted by the jacket to the cylinder, a saving within the latter of 3·366 units by the prevention of condensation.

In the preceding discussion, the loss of heat by external radiation, when steam was not in the jacket, has been assumed to be the same as when steam was in the jacket, which is not quite true, as in the former case this loss must have been much less, owing to the considerably less surface exposed; the assumption, therefore, is against the steam-jacket, making its economic efficiency appear somewhat less than it really is. I have done the best I could, however, with the data at my command, but the reader must remember that the engine was not properly designed for making critically accurate experiments. The results, nevertheless, are reasonably correct, and are far too valuable to be rejected because all the conditions were not just what they could have been wished.

THE QUANTITY OF STEAM CONDENSED IN THE CYLINDER BY CAUSES OTHER THAN DUE TO EXTERNAL RADIATION AND TO THE PRODUCTION OF THE POWER.

It is very evident there must always be a condensation of steam in a steam-engine, due to external radiation of heat. So long as the surrounding atmosphere is at a less temperature than that of the steam within the cylinder, so long will there be a condensation of steam, let the cylinder be enveloped with what non-conducting substance it may. This is an inevitable waste of steam in an engine easily understood, and the only question is to reduce it as much as possible by the employment of the best non-conducting envelope. In the experimental engine, the loss of steam from this cause alone averaged 7 per centum of the steam evaporated in the boiler. That is to say, the condensation in the steam-pipe and engine, exclusive of the condensation in the boiler, averaged this quantity.

It is equally evident that there is another cause of condensation in steam-engines just as inevitable as the preceding, and this condensation, resulting from the necessary transformation of heat into the total power developed, takes place when the steam is used without expansion, not only in the cylinder, but in the steam-pipe and boiler, in fact, everywhere between the water-level in the latter and the piston in the former. When, however, the steam is used with expansion, the condensation after the communication with the boiler is closed, takes place in the cylinder only. The shorter the cut-off, therefore, the more of this condensation takes place in the cylinder.

In experiment A, with steam in the jacket and the cut off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the produc-

tion of the power was 8·28 per centum of the quantity of steam evaporated in the boiler; but it was 9·72 per centum of the quantity of steam which actually entered the cylinder. Yet even after taking account of this condensation and of those due to external radiation and to the impartation of heat by the steam-jacket to the cylinder, and also of the quantity of steam exhausted at the end of the stroke of the piston, line 22, there still remains an unaccounted for balance, line 26, of 11·40 per centum of the quantity of steam evaporated in the boiler. How could this large per centum have escaped measurement? By simple re-evaporation from the cylinder's inner surfaces and passage out into the atmosphere as vapor during the exhaust stroke of the cylinder. The steam-jacket, efficient as it was, was not able to prevent this large condensation in the cylinder; and doubtless more too, but the re-evaporation of which, under the lessening pressure during the steam stroke after the cut-off valve closed, by means of its contained heat and that absorbed from the cylinder's inner surfaces, took place before the end of the stroke of the piston, and was therefore measured in the quantity on line 22.

Again, in experiment C, with the steam in the jacket, and the cut-off at $\frac{2}{3}$ of the stroke of the piston, the condensation of steam due to the production of the power was 7·24 per centum of the quantity of steam evaporated in the boiler; but it was 7·91 per centum of the quantity of steam which actually entered the cylinder. In this case, as in the previous one, there still remains a considerable quantity of steam unaccounted for, after including the condensations due to the external radiation and to the production of the power, with the quantity of steam exhausted at the end of the stroke of the piston (line 22); but this unaccounted for quantity is much less with the longer cut-off, being only, with the $\frac{2}{3}$ cut-off, 4·45 per centum of the quantity of the steam evaporated in the boiler, instead of the 11·40 per centum with the $\frac{3}{8}$ cut-off, showing that the shorter the cut-off, the greater is the cylinder condensation due to other causes than external radiation and the production of the power. As, in the preceding case, too, this unaccounted for portion of condensed steam was re-evaporated from the inner cylinder surfaces into the atmosphere during the exhaust stroke of the piston.

Finally, in experiment E, with steam in the jacket, and the cut-off at $\frac{2}{3}$ of the stroke of the piston, the condensation of steam due to the production of the power was 7·16 per centum of the quantity of steam

evaporated in the boiler; but it was 8·33 per centum of the quantity of steam which actually entered the cylinder. In this case, the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than due to the external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 4·90 per centum of the quantity evaporated in the boiler.

The preceding three determinations for experiments A, C, and E, are for the condition of steam in the jacket. When, however, there is no steam in the jacket, as in experiments B, D, and F, the condensation of steam in the cylinder by causes other than those due to external radiation and to the production of the power, is very much greater. In these experiments, too, as in the preceding ones, this enormous quantity of steam after being condensed in the cylinder is re-evaporated into the atmosphere during the exhaust stroke of the piston.

For instance: in experiment B, with no steam in the jacket, and the cut-off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the production of the power was 7·05 per centum of the quantity of steam evaporated in the boiler; but it was 7·70 per centum of the quantity of steam which actually entered the cylinder less the quantity condensed by external radiation. In this case, the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than those due to external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 26·41 per centum of the quantity evaporated in the boiler, or about $2\frac{1}{2}$ times as much as in the case (experiment A) when steam was in the jacket, other things being equal.

Again, in experiment D, with no steam in the jacket, and the cut-off at $\frac{2}{3}$ of the stroke of the piston, the condensation of steam due to the production of the power was 6·56 per centum of the quantity of steam evaporated in the boiler; but it was 6·93 per centum of the quantity of steam which actually entered the cylinder less the quantity condensed by external radiation. In this case the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than those due to external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 16·77 per centum of the quantity evaporated in the boiler, or about 4 times as much as in the case (experiment C) when steam was in the jacket, other things being equal.

Finally, in experiment F, with no steam in the jacket, and the cut-off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the production of the power was 6·14 per centum of the quantity of steam evaporated in the boiler; but it was 6·61 per centum of the quantity of steam which actually entered the cylinder less the quantity condensed by external radiation. In this case the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than those due to external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 19·76 per centum of the quantity evaporated in the boiler, or about 4 times as much as in the case (experiment E) when steam was in the jacket, other things being equal.

The experiments above discussed have a particular interest at the present time, owing to the extensive introduction of the compound engine with steam-jackets, high pressure steam, and excessively large measures of expansion; and to its superseding, in great degree, the ordinary steam-engine without steam-jackets and with steam of medium pressure used with small measures of expansion. The compound engine does indeed give an economic superiority ranging from one-fifth for medium sized engines, to one eighth for large ones; but this economy is due wholly and solely to the employment of the steam-jacket, and vanishes whenever the ordinary steam-engine is steam-jacketed also. The higher pressures and greater measures of expansion used with the compound engine are absolutely unproductive of any economic effect, their disadvantages just about balancing their advantages, but leaving all the very serious mechanical difficulties due to the higher pressures, heavier and bulkier boilers, and larger cylinders for the development of equal power, on the side of the compound engine. All that is required to give the ordinary steam-engine, when in good condition, the same economic result as the compound engine, is to simply steam-jacket its cylinder, without changing either the steam-pressure or measure of expansion used. The mistake has been made of attributing to the mere compounding of the cylinders, a result due entirely to the use of the steam-jacket, an appendage as easily applied to the one kind of engine as the other. It was quite overlooked in comparing the experimental economic results from the compound and the ordinary engine, that the former had been given the advantage of a steam jacket which was omitted in the other. Whenever the steam jacket was used in both cases, the results were equal.

EFFICIENCY OF FURNACES BURNING WET FUEL.

AS DETERMINED BY EXPERIMENTS ON A LARGE SCALE.

By Professor R. H. Thurston, A. M., C. E.

A Paper read before the American Society of Civil Engineers, October 21st, 1874.

(Continued from Volume lxix, page 59.)

CONCLUSION.

45. Comparing the quantities of heat actually utilized by transfer from the fuel to the boiler, we obtain as the measure of the actual comparative efficiencies of the two furnaces $4{\cdot}24 \div 3{\cdot}19 = 1{\cdot}33$, the Thompson excelling the Crockett 33 per cent. A number of circumstances combine to make the actual difference somewhat greater than the record here indicates, but this result may probably be taken to represent practically the relative economical standing of the two furnaces.

46. Experiments on dry pine wood, made by Prof. Johnson during his extended and invaluable examination of American coals,* for the U. S. Navy, furnish a standard of comparison which will be useful here. One cord of well-seasoned yellow pine wood weighed 2689·2 pounds—10 per cent. more than a cord of thoroughly air-dried spent tan bark—and one cubic foot weighed 21 pounds. Experiments on evaporative power showed, as a mean result, an effect equivalent to the evaporation of 4·69 pounds of water from 212°, under atmospheric pressure, per pound of wood consumed, the temperature of chimney flue being 315·2°, and the wood burning at the rate of 15.87 pounds per square foot of grate per hour, under a boiler having a ratio of heating to grate surface of 26·83 to 1.

47. Comparing this result, as a standard, with the evaporation obtained in the two wet fuel furnaces, per pound of fuel, exclusive of water, we get for the Thompson furnace $\frac{5{\cdot}68}{4{\cdot}69} = 1{\cdot}21$, and for the Crockett, $\frac{4{\cdot}41}{4{\cdot}69} = 0{\cdot}94$. The Thompson furnace is thus seen to have given a better result per pound of ligneous combustible when burning wet tan than was obtained in the ordinary steam-boiler furnace, burning seasoned yellow pine, this superiority reaching 21 per cent. The

* Report to the Navy Department on American Coals. By Walter R. Johnson Washington, 1844, pp. 546–550.

Crockett furnace had 94 per cent. of the efficiency of the common wood-burning steam-boiler furnace.

48. The relative efficiency of fuel, comparing wet tan with dry wood, by weight, the former containing between 55 and 60 per cent. of water, becomes $\frac{4\cdot24}{4\cdot69} \times 100 = 90\cdot40$ per cent., each fuel being consumed under the most favorable conditions shown above, and equal weight of ligneous fuel being taken for comparison.

A cord of dry yellow pine, as per experiments of Prof. Johnson, evaporated 12618·3 pounds of water. A cord of wet, spent tan, burned in the Thompson furnace was equivalent to $\frac{9459\cdot2}{12618\cdot3} = 0\cdot75$ cord of dry wood. One cord of wet spent tan burned in the Crockett furnace, was equivalent to $\frac{7103\cdot84}{12618\cdot3} = 0\cdot56$ cord of dry yellow pine.

49. A cord of dry yellow pine is approximately equal in heating power to 0·6 of a ton of coal, and, conversely, the ton of good coal is equal in calorific power to 1·66 cords of soft wood. An average pound of dry wood is theoretically capable of evaporating 6·66 pounds of water from and at 212°. A pound of good anthracite, similarly, should evaporate 13·5 pounds of water.

The "absolute efficiencies" of coal and wood, under the conditions already described in the several cases mentioned, are as follows: coal 70 per cent.; wood—in the Crockett furnace, 66 per cent., in the ordinary steam-boiler furnace, 70 per cent., and in the Thompson furnace, 85 per cent.—reckoning the evaporation of the moisture in the fuel. Excluding this moisture, the percentages become respectively 70, 48, 70 and 64.

THEORY OF FURNACES.

50. The data obtained at these trials are sufficiently complete to furnish a basis upon which to construct the theory of action of each furnace, and to give approximate determinations of quantities which are of importance in that connection, and of interest in their bearing upon practical deductions. The most important points are the temperatures of furnace and of chimney flue, the quantity of air supplied, and the effect of variations of area of heating surface of boilers.

TEMPERATURES OF FURNACE AND OF CHIMNEY FLUE.

51. An approximate determination of the temperature of furnace can be made, in this case, in the following manner:

The fuel used at this furnace, as taken from the leach, contained more than one-half its weight of water. In handling, it lost some of this moisture. When thrown upon the top of the furnace and before it was thrown upon the fire, it, by its non-conducting property, prevented to some extent loss of heat, and such heat as was absorbed by it was usefully employed in evaporating its moisture. The quantity of water thus lost before entering the furnace may be estimated approximately at about one per cent. in handling, and 3 per cent. at the furnace. Box, in his "Treatise on Heat," gives the total loss of temperature by conduction and radiation, in a fire-brick furnace, as 10 per cent. Here, several long ovens were placed side by side, and the principal loss was that from the top. Very little could take place laterally, and no heat could pass downward.

The total loss here may be taken as $2\frac{1}{2}$ per cent., which would so change the composition of the wet fuel as to leave it with 3 per cent. less water, making it about 45 per cent. combustible and 55 per cent. water.

Taking the available heat per pound of the dry portion, at 6480 thermal units, each pound of wet fuel yields 2916 units of heat. Of this, 531·6 are absorbed in the evaporation of the 55 per cent. of water, leaving 2384·4 units to raise the temperature of the products of combustion. Of these there are, as a minimum, 3·7 pounds having a mean specific heat of about 0·287.

The elevation of temperature is therefore 2245 3°, and adding the mean temperature of the atmosphere, 74°, the mean temperature of furnace, assuming no dilution with unused air and no losses, would have been about 2320°. Losing about $2\frac{1}{2}$ per cent., the temperature becomes 2260°.

The temperature of chimney flue was found by experiment to have been 544°. The furnace gases were therefore cooled $2260° - 544° = 1716°$ by the loss of heat given up to the boiler. This is equivalent to $1716 \times 0·287 = 492·5$ heat units per pound of gas, and to 4049·4 units per pound of ligneous material in the fuel.

The "equivalent evaporation" from and at 212° is $4049·4 \div 966·6 = 4·18$ pounds of water. The actual exaporation was equivalent to

4·24 pounds, and the difference—less than one per cent.—repressent losses and errors of approximation.

52. The actual existing temperature of furnace can be thus estimated: the available heat per pound of fuel, excluding water, has been given at 2916 thermal units. Of this $\frac{531 \cdot 6}{2916} = 0 \cdot 182$ was not useful in raising the temperature of either the furnace or the chimney. Hence, of all heat liberated, $1 \cdot 00 - 0 \cdot 182 = 0 \cdot 818$* was efficient in elevating the temperature of furnace, and $0 \cdot 37 - 0 \cdot 182 = 0 \cdot 188$ was effective in producing the observed temperature, 544° of chimney. Then, since the same quantity of gas passes at both places, the temperature of furnace was $\left(\frac{0 \cdot 818}{0 \cdot 188} \times 470\right) + 74° = 2118 \cdot 5°$. To this is to be added the slight loss of temperature, *en route* between furnace and chimney, by conduction and radiation.

DETERMINATION OF AIR SUPPLY.

53. The air supply of the Thompson furnace is unusually restricted as has already been noted.

Instead of an ash-pit with a front entirely open, we find here closed ash-pit doors, and no other opening for the passage of air than the comparatively small orifices in the registers with which the doors are fitted. The usual amount of air supplied, in furnaces burning coal, is generally given as about twice the theoretically required quantity, giving a temperature of about 2400°. In exceptional cases, the air supply falls as low as one and a half times the theoretically required amount, the temperature reaching about 3000°. In such cases, it sometimes happens that the grates are melted down, cast-iron melting at between 2700° and 2800°.

In the Thompson furnace, with an ash-pit fire, this is very likely to take place with iron grates, and the inventor was therefore driven to the use of fire-brick grates. The mean temperature of the products of combustion is, however, lower, notwithstanding the restricted air supply, in consequence of the presence of moisture.

The quantity of air supplied is calculated as follows: The difference between the theoretical and the actual temperature of furnace,

* Assuming 6480 units as the heating power of the tan when dried, the efficiency of this furnace becomes 0·63, and 0·37 of the total heat of the fuel passes off by the chimney.

as above estimated, is 2260° — 2118° = 142°, corresponding to $142 \times 0{\cdot}287 = 40{\cdot}75$ thermal units per pound of gas, or $40{\cdot}75 \times 3{\cdot}7 = 150{\cdot}8$ units per pound wet fuel, and $150{\cdot}8 \div 0{\cdot}45 = 335{\cdot}1$ units per pound of wood, which heat was distributed through the air diluting the products of combustion.

This latter amount is sufficient to heat $(335{\cdot}1 \div 0{\cdot}238) \div 2044 = 0{\cdot}69$ pounds of air from the temperature of the external air 74° to 2118°. The theoretically required quantity of air per pound of wood is 6 pounds; hence the products of combustion at the Thompson furnace were diluted with 12 per cent. of air; this is one-fourth that of ordinary practice with coal fires.

TEMPERATURES IN THE CROCKETT FURNACE.

54. The temperature of chimney flue not being known, the estimates of temperature of furnace and of air supply cannot be so satisfactorily determined for the Crockett furnace. The following may, in the opinion of the writer, be taken as a fair approximation.

The composition of the fuel, in this case, was slightly changed in handling, between the leach and the furnace, as before. Lying in front of the furnace also, a small amount of drying must have occurred by radiated heat. Taking the total amount of both influences as producing an alteration of 2 per cent. in the composition of the fuel, it becomes 52 per cent. water and 48 per cent. dry wood.

55. The theoretical temperature of furnace gases, estimated as before, is reduced largely in this case, by the air of dilution. The fuel was burned at the rate of about 20 pounds per square foot of grate per hour, and the weight of carbon, the only valuable heat-producing element, was 5 pounds per square foot of grate per hour. The bulky character of the fuel compelled the opening of the doors, in charging the furnace, about once in seven or eight minutes. The fire burned somewhat irregularly into holes, allowing an unusual amount of air to pass up unutilized.

In ordinary practice, with anthracite coal fires, the fuel burns, with such draught as was found at the Crockett furnace, at the rate of about 10 pounds carbon per square foot of grate per hour. The doors are opened about once in fifteen or twenty minutes, and the air supply is about 240 pounds per square foot of grate surface per hour.

56. The air supply at the Crockett furnace was apparently in excess of that just given, by a large amount. Neglecting this ex-

cess, and calculating the temperature of the furnace as if the air supply were the same as with coal, the following results are obtained:

Available heat per pound wet tan, . .	3110·4 units.
Rendered latent by evaporating 52 per cent. water,	503·6 "
Effective in elevating temperature, . . .	2606 8 "

This was distributed through 12·5 pounds of gaseous products of combustion, of a mean specific heat, 0·25. The elevation of temperature was therefore 832·8°, and adding the mean temperature of external air, we obtain for the average temperature of gases escaping from the furnace, including cold air streaming through the furnace doors and the holes in the fire, 919·3°, or about 100° above the temperature at which combustible gases can take fire.

Taking the air supply as possibly, at times, as low as that considered the minimum with ordinary coal fires, 180 pounds per square foot of grate per hour, where burning fuel with sluggish draught, the temperature of furnace at such times becomes 1150·3°.

57. The temperature of chimney flue may be readily estimated for these conditions. Referring the performance of this furnace, like the preceding, to "dry wood" as a standard, its efficiency is 47 per cent. Hence 53 per cent. of the heat obtainable from the fuel passes off by the chimney. The loss of heat by the escape of unburned carbon in the form of smoke, although more than at the other furnace, was not probably sufficient to be here taken into account. The following are the estimates:

Available heat per pound of wet tan, . .	3110·4 units.
Passing up chimney, 53 per cent., . .	1648·5 "
" " latent in vapor, . .	503·6 "
" " elevating temperature, .	1144·9 "

This was distributed throughout 12·52 pounds of gas, where the usual supply of air was maintained, and through 9·64 pounds in the case of less free supply, supposed possible at times.

The heat per pound of gas amounts to 91·4 units for the first case, elevating the temperature $91{\cdot}4 \div 0{\cdot}25 = 365{\cdot}6°$ above that of the atmosphere, or to 452°.

Under the other supposed conditions, the elevation of temperature of chimney becomes 467·7°.

To secure an economy at this furnace equal to that obtained at the Thompson furnace, it would be necessary to reduce the quantity of heat carried off by the chimney gases, in the proportion of 53 to 37.

One-third of this heat is latent in the vapor of water, and no part of that can be secured. The requisite reduction of temperature of gases to effect this economy is thus exaggerated; and it would be necessary, were such a thing possible, to bring down the temperature of chimney to between 140° and 160°, to a temperature 160° or 140° below that of the boiler itself, or to less than one-fourth that required for most efficient draught.

EFFICIENCY OF FURNACES.

58. In determining the precise value of two competing sets of apparatus, as generators of heat, it is necessary first to obtain from each its best performance in producing heat, and then to provide means of absorbing and utilizing that heat with equal thoroughness in both cases.

The proper area of heating surface of boilers will therefore vary with each case. The same area, where the furnaces themselves differ considerably, may, in the one case, allow a waste of heat, while in the other it may reduce the temperature of gases so far as to compel the adoption of a "mechanical draught." In the cases here considered, the area of heating surface was fortunately very nicely adapted in each instance to the requirements of the case. In both examples, the temperature of chimney flue is found to be somewhat below that required for most efficient draught; but was not far different in the two cases, the less economical furnace having the economical advantage of such difference as did exist.

The trial, therefore, exhibits very fairly the intrinsic values of these two furnaces as heat-generating apparatus, and of these two radically different methods of working them, as taken apart from the efficiency of heat absorbing or heat utilizing contrivances.

59. The importance of high temperature of furnace is strikingly and beautifully illustrated by these results. The two furnaces develop practically the same amount of heat from the fuel, but the one distributes it through a large volume of gases at low temperature, sending a considerable proportion of it up the chimney, while the other raises a small volume of gas to a much higher temperature, making it more available to the extent of 33 per cent., and finally, even then sending up the chimney gases of higher temperature than the first.

The abstract *efficiency of the furnace* in any ordinary case is represented by the formulas—

$$\mathfrak{E}' = \frac{\tau_1 - \tau_2}{\tau_3 - \tau_1} = \frac{T_1 - T_2}{T_1 - T_3}$$

Where $\mathfrak{E}'$ represents the efficiency and τ_1 and τ_2 are the absolute temperatures at which the heat is generated, and at which wasted heat is discharged, and τ_3 that of the external air, T_1, T_2, T_3, are temperatures on the Fahrenheit scale.

In these cases $\mathfrak{E}' = \dfrac{2118° - 544° \text{F.}}{2118° - 74} = 0{\cdot}77.$

$$\mathfrak{E}'' = \frac{919° - 452°}{919° - 86.5} = 0\ 56.$$

60. These values do not represent the *efficiency of the fuel*, including the vaporization of water contained within itself. In these cases the heat lost, as latent in vaporization, before the generation of these temperatures, is to be deducted to give the total efficiencies of the fuel, which thus are found to have the values $0{\cdot}77\ (1 - 0{\cdot}182) = 0{\cdot}63$ and $0{\cdot}56\ (1 - 0{\cdot}175) = 0{\cdot}46$.

The experimental determinations were 0·64 and 0·48, if referred to seasoned wood, and 0·63 and 0·47 when referred, as here, to dry wood of a calorific value of 6480 heat units.

To make the values of $\mathfrak{E}$ comparable with the standard already assumed for *final absolute efficiency*, per experiment, it is necessary to add 9 per cent. to the first values of $\mathfrak{E}$, in each case, in order to credit the fuel with the heat used in the vaporization of its water, and with the heat carried by the vapor up the chimney.

Thus the values $0{\cdot}77 + 0{\cdot}09 = 0{\cdot}86$, and $0{\cdot}56 + 0{\cdot}09 = 0{\cdot}65$ are deduced. These ratios, by experimental determination, were 0·86 and 0·67. The correspondence of these figures with those just deduced theoretically, is a remarkably conclusive evidence of the accuracy of the estimated temperature and of the fact that the difference of efficiency found by trial is due to such difference of temperature. The accordance is unusually precise.

EFFECTS OF AREA OF HEATING SURFACE.

61. Rankine has given a formula* for determining the efficiency of fuel in ordinary steam boiler practice, where the ratio of the area of heating surface, and of fuel burned per hour, to the square foot of grate surface, is known :—

$$\frac{E^1}{E} = \frac{B\,S}{S + A\,F},$$

in which $\dfrac{E^1}{E}$ is the quantity called above $\mathfrak{E}'$, A and B are constants,

*Steam Engines and Prime Movers, p. 292, § IV.

and F and S are the ratio of fuel burned per hour to the square foot of grate, and the ratio of area of heating surface to grate area.

For the cases here considered, $A = 0{\cdot}5$, and $B = 0{\cdot}92$, $S = 8{\cdot}5$ for the Thompson, and $14{\cdot}5$ for the Crockett furnace, $F = 1{\cdot}38$, and $5{\cdot}3$; $\frac{F}{S}$ becomes $0{\cdot}13$ and $0{\cdot}36$, and the value of $\frac{E^1}{E}$ is, for the Thompson $0{\cdot}859$, and for the Crockett furnace $0{\cdot}776$.

Were this formula applicable to these cases, the experimental determinations of efficiency should coincide with these, but they are 0·64 and 0·48. This difference is a consequence of the facts that the fuel used in these furnaces was wet, and that the large proportion of heat absorbed by the water was so much abstracted from the efficiency of the fuel. Thus the absolute values are reduced.

They differ, also, in consequence of the important fact exhibited in the preceding paragraphs, that the temperature of furnace differs in each case (and in the case of the Crockett furnace immensely), from the temperature, 2400°, given by Rankine as the mean temperature of furnaces to which his formula is adapted. This changes relative values.

The value 0 859, for the Thompson furnace, is almost precisely that obtained by experiment—"including water in fuel," 0·86—as it should be, since the temperature of that furnace, 2118°, is not far different from that of the ordinary coal fire. The value, 0 776, for the Crockett furnace differs greatly from that formed by experiment—"including water in fuel," 0·67—as would be expected in consequence of the exceptionally low temperature of that furnace.

The difference between these two theoretical values, $0{\cdot}859 - 0{\cdot}776 = 0{\cdot}083$, would represent approximately the loss of total absolute efficiency that might be expected, were the case one of ordinary practice, and were the Thompson furnace supplied with boilers of as small a ratio of heating surface to fuel consumed, $\frac{F}{S}$ as the Crockett furnace actually had.

The difference which would readily be produced would be less in consequence of a circumstance, peculiar to that example, of which the influence has not been noticed by writers on this branch of the theory of engineering.

62. The rate of conduction of heat from the furnace gases to the heating surfaces with which they are in contact varies, in some not

well determined ratio, with the difference of temperature. It may be represented approximately, according to experiments of Charles Wye Williams,* and judging from the analysis of M. Paul Havrez,† by a hyperbolic curve, of which the equation is $x\,y = A$, y representing the evaporation for a unit of area of a tube at a distance x from the furnace.

$$U = B \log x$$

is the equation of total evaporation.

When the volume of gas is the same, as in cases to which the formula of Rankine applies, the constants in these equations are the same, and his formula gives a remarkably satisfactory approximation. Where, as in the Thompson furnace, the restriction of the air supply causes a comparatively slow movement of gases along the heating surface, the value of that portion nearest the fire becomes enhanced, leaving the furthest portions of less efficiency.

The effect of reducing the air supply nearly one-half would, therefore, be to actually reduce greatly the amount of the theoretical loss, 0·08, just given. The real loss would be somewhere between this 8 per cent. and the smaller differences noticed between the theoretical estimates of efficiency of fuel and the actual differences shown by experiment. This latter consideration may, perhaps, be taken as a proof that this difference of efficiency due to such a change of heating surface, would amount approximately to 2 per cent. Were more steam wanted, this would be at once sacrificed at the Thompson furnace, to bring the temperature of chimney up to that, 645°, which would give most efficient draught.

63. At the Crockett furnace, the effect of the exceptionally low temperature of furnace is to equalize the value of heating surface; and the considerable velocity of the gaseous current, which is a consequence of the unusually great volume of air passing through the furnace, increases this effect. The nearer surface is inefficient, and the most distant portions of the heating surface are therefore proportionally much more efficient than in the preceding case.

Extension of surface is, however, precluded by the fact that the temperature of escaping gases would fall still further below that re-

* "On the Steam Generating Power of Marine and Locomotive Boilers."—London, 1864.

† "Evaporisation decroissante en Progression Geometrique dans les Chaudieres."—Revue Industrielle, 1874.

quired for effective draught, and, as already indicated, were it possible to operate the furnace at all, this temperature would become one-half the temperature of the boiler, were so much heat abstracted as to give an efficiency of fuel equal to that obtained in the other furnace. Heat would then pass from the boiler to the gas at those portions of its surface farthest from the fire, and the draught could only be maintained by means of special "blowing" apparatus. This is another fact illustrating the importance of high temperature of furnace in the attainment of high furnace efficiency.

64. The table given on the following page presents the results of the above investigation in a concise form, in which it may be found very useful for reference.

65. Both of these furnaces were introduced about twenty years ago, and the first is in somewhat extensive use. No experimental determination of their actual relative efficiencies has ever been made before, so far as the writer is aware which has enabled their theory to be worked out. The determination of their theory, as here given, has greatly interested him, and will, perhaps, prove as interesting to the profession. It may be found of value, in view of the many important applications which are daily being made of the various kinds of wet fuel.

The temperatures, as given, may be somewhat below actual temperatures where they are determined from the composition of fuel, as the calculations are made on the assumption that all vapors issuing from the fuel are raised to the mean temperature estimated. The real fact is, that they are expelled while the temperature of issuing gases is reduced by their presence, and they therefore do not abstract as much heat as is debited to them in the calculation.

During those intervals of time which elapse between the drying of one charge and the introduction of the next, the temperature of furnace rises to that due to the combustion of dry fuel. The results, as given, are probably, however, practically and sufficiently correct.

RESULTS OF TRIALS OF FURNACES BURNING WET SPENT TAN BARK, AUGUST, 1874.

KIND OF FURNACE.	Fuel.	Percentage		Total weights pounds.			Steam.	Priming	Percentages		British thermal units per cord of tan	Apparent evaporation.				Actual evaporation.		Ratio of air supply to theoretical.
		Water.	Combustible.	Fuel.	Combustible.	Feed.			Priming to feed.	Priming to steam.		Per cord fuel.	Per pound combustible.	Per sq. ft. grate per hour.	Per sq. ft. heat surf. per hour.	Per lb. of fuel.	Per lb. combustible.	
Thompson.	Tan........	59	41	44945	17198·41	73125	68393·8	4731·2	6·47	6·92	9143321·4	9596 75	4 25	23 7	2 81	1·3	3·98	1·12
Crockett..	Tan........	55	45	22336	10051·20	28509	24774·32	3734·68	13·1	15·	6866576·75	6335 33	2 83	65 9	4 52	......	2·46	8·
Ordinary st'm boiler	Pine wood.	......	80	....	2360·50	....	....	....	.....	......	....	10891·26	4·05	61 5	2 29	4·05	4·03	......
Ordinary st'm boiler	Anthracite Coal.....	......	91	....	....	....	....	....	......	6	....	....	8 75	95·	3 00	7·35	8·75	2·

KIND OF FURNACE.	Approximate estimate mean temperature of furnace gas, Fahrenheit.		Equivalent evaporation per 212° F. per lb., including water in fuel.	Equivalent evaporation from 212° F. per lb., excluding water in fuel.	Relative efficiency excluding water in fuel —Crockett = 1.	Relative efficiency excluding water in fuel—wood = 1.	Relative efficiency including in account water in fuel-Crockett = 1.	Relative efficiency including water in fuel—wood = 1.	Absolute efficiencies, water in the fuel			
									excluded		included, dry wood as stand'd	
	Furnace	Flue.							Standard of 6385 units.	Dry wood of 6480 units.	of 6385 units.	of 6480 units.
Thompson...........................	2118°	544°	5·68	4·24	1 33	0·90	1·29	1·21	0·64	0·63	0·85	0·86
Crockett............................	919°	452°	4·41	3 19	1·00	0·68	1·00	0·94	0·48	0·47	0·66	0·67
Ordinary steam boiler...............	....	....	4·69	4·69	1·47	1·00	1·06	1·00	0·70	0·70	0·70	0·70
Ordinary steam boiler...............	2400°	700°	10·50	10·50	3·28	2·23	2·37	2·23	0·70	0·70	0·70	0·70

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxix, page 69.]

The principle of the improvement is now complete so far as concerns the relative movement of the hammer drop and the valve, but there must be some principle applied for the extraneous movement of this added mechanism. Looking around for examples, we can see that where movement continues after the force which produced it has ceased to act, the principle is in nearly every case that of momentum. We see cannon balls travel for miles, the impelling force acting for a few feet only, or the weaver's shuttle performing its flight after the driver has stopped its movement, and it may be safely assumed in this case that momentum is the available force to produce this independent movement required in the valve gearing.

To sum up, it has been determined by inductive reasoning coupled with some knowledge of mechanics, that a steam hammer, to give a dead blow, requires the following conditions in the valve gearing:

First. That the drop and valve, while they must act relatively, cannot move in the same time, or in direct unison.

Second. The connection between the hammer drop and valve cannot be positive, but must be broken during the descent of the drop.

Third. The valve must move after the hammer stops.

Fourth. To cause a movement of the valve after the hammer stops there must be an intermediate agent, that will continue to act after the movement of the hammer drop has ceased.

Fifth. The obvious means of attaining this independent movement of the valve gear is by the momentum of some part set in motion by the descent of the hammer.

The invention is now complete, and as the principles are all within the scope of practical mechanism, there is nothing left to do but to devise such mechanical expedients as will carry out the principles laid down. This mechanical scheming is a second and in some sense an independent part of machine improvement, and should always be subservient to principles; in fact, to have it precede principles, constitutes chance invention or chance scheming. That it is to be re-

garded in a sense distinct from dealing with mechanical principles, is evident from the fact that a man may have this faculty of mechanical scheming developed in an extraordinary manner, and yet be comparatively ignorant of the principles of mechanism.

Referring again to the hammer problem, the apprentice will find by examining the subject that the builders of automatic acting steam hammers that are capable of giving the dead stamp blow, have employed the principles that have been described, with perhaps the single exception of Messrs. Schwartzkopf, German engineers, who, instead of employing the momentum of moving parts to open the valve after the hammer stops, depend upon disengaging valve gear by the concussion and jar of the blow, the valve gear by its gravity opening the valve. The eminence of German engineers in this particular branch of mechanical engineering is, however, such that they have no doubt adopted various devices besides the one just described.

I will not consume space to describe the converse of this logical system of inventing, nor to picture a chance schemer hunting after mechanical expedients to accomplish the valve movement in the example that has been given. The reader can do this for himself, and no doubt has done so as he went along.

Inventions in machine improvement, no matter what their nature, must of course consist in and conform to certain fixed principles, and no plan of urging the truth of a proposition is so common, even with the chance inventor, as to trace out the principles that govern his discovery. This is hence a negative course, useful in its place, to confirm and further explain what may have been demonstrated by accident, but the true plan is to proceed in the other direction, from principles to practice, the course that is here recommended to the apprentice in his attempts to invent.

In studying improvements with a view to practical gain, the learner can have no reasonable hope of accomplishing much in fields already gone over by able engineers, nor in demonstrating anything new in what we may call exhausted subjects, such as steam engines or water wheels; but should choose rather new and special subjects, and above all things avoid radical innovations upon existing views or existing practice.

It has been already remarked that the boldness of young engineers is very apt to be inversely as their experience, not to say their want of knowledge, and it is only by a strong and determined effort

towards conservatism, that a true balance is maintained in judging of new schemes.

I will end this article by citing the reader to some examples illustrating the general plans that have been briefly laid down in regard to inventions

The life of George Stephenson, if studied, will prove that notwithstanding the novelty and great importance of his improvements in steam transit, he did not "discover" these improvements. He did not discover that a floating embankment would carry a railway across Chat Moss, neither did he discover that the friction between the wheels of a locomotive and the rails would enable tractive power to draw a train. Everything connected with his history shows that all of his deductions were founded upon a method of reasoning from principles inductively, and to say that he "discovered" our railway system, according to the ordinary construction of the term, would be to detract from his hard and well-earned reputation and place him among a class of fortunate schemers who can claim no place in the history of legitimate engineering.

Count Rumford did not chance upon the new philosophy of forces upon which the whole science of dynamics now rests; he set out upon a methodical plan to demonstrate conceptions that were already matured in his mind, and to verify principles which he had assumed by deductive reasoning; in fact, all great and substantial improvements that have performed any considerable part in developing modern mechanics, have come through this natural course of first dealing with primary principles, instead of groping about blindly after mechanical expedients.

WORK SHOP EXPERIENCE.

I have now reached that part of this article that may be of most interest and perhaps of most use to the engineering apprentice, especially those who are not able to avail themselves of the advantages of a course in the draughting and pattern department, or in the commercial department of the works where they may be engaged.

To argue the necessity of learning practical fitting as a part of an engineering education would be superfluous. The mechanical engineer that has not been "through the shop" can never expect to attain success, nor command the respect even of the most inferior workmen, and without this power of influencing others, he is neither

fitted to direct construction, nor to manage details of any kind connected with engineering industry, nor even to keep records.

There is nothing that more provokes a feeling of resentment in the mind of a skilled man than to meet with those who have qualified themselves in the theoretical and commercial details of engineering work, and then attempt to direct the labor which they do not understand; nor is a skilled man long in detecting an engineer of this class; a dozen words in conversation upon any mechanical subject is generally enough to furnish a clue to the amount of practical knowledge possessed by the speaker.

The reasons for a shop course are many; the main one, perhaps, being to learn the nature of fitting operations which must continually modify the plans of construction, and determine cost. As remarked in a previous place, no one can prepare successful designs for machinery, who does not understand the details of its construction; he should know how each piece is moulded, forged, turned, planed or bored, and the relative cost of these processes by the different plans that may present themselves to his mind.

The influence over workmen and under-managers is always dependent upon the practical knowledge of the person in general charge. An engineer may direct and control a work without a knowledge of practical fitting, but such control is merely a commercial one and cannot of course extend to mechanical details which are generally the vital part; and the obedience that may be enforced is not to be confounded with the respect that superior knowledge always commands.

Another gain from learning practical fitting is the confidence that such knowledge inspires in either the direction of work or the preparation of plans for machinery. The man who hesitates in his plans for fear of criticism, or who does not feel a perfect confidence in his own deductions, will never achieve much success. It requires not only the highest powers of the mind to generate plans for machinery and to direct construction successfully, but also requires that the mind be unfettered by the restraints that have been indicated.

The changes that have totally revolutionized machine fitting during thirty years past, have been of a character to dispense with hand skill, and supplant it with what may be termed mental skill. The mere physical effect that may be produced with a man's hands, has steadily diminished in value until now it has almost come to be reckoned in foot pounds. The same remark applies in some degree to

hand skill, which now holds a place quite different from what it did even twenty years ago.

Once the apprentice entered the shop to learn a certain amount of hand skill, and to acquaint himself with a number of mysterious processes, and to learn a series of arbitrary rules which might place him at a disadvantage even with those whose mental capacity was inferior and who had less education; but now the whole is changed. An engineering apprentice enters the shop with a confidence that he may learn whatever the facilities afford, if he will put forth the mental effort needed, and that there are no mysteries to be learned which are not reached and explained by the physical sciences. In short, to learn machine fitting at the present time is but a small matter compared with twenty years ago, provided the learner sets out properly prepared and with intelligent views of what he is to undertake.

This change in engineering pursuits has also produced a change in the workmen almost as thorough as that in the manipulation. A man who deals with special knowledge and feels that the secrets of his calling are not governed by general rules, that may qualify others without his assistance, is always more or less narrow-minded and ignorant. The nature of his relations to others makes him so; of this no better proof is wanted than to contrast the intelligence of workmen who are engaged in exclusive callings, with those whose pursuits are regulated by general rules and principles. The machinist of modern times, at least in the more enlightened countries, having outgrown what we may term mechanical superstition, has thereby been raised to a social position that is confessedly superior to that of other mechanics, so that shop associations that were once so dreaded by those who would otherwise have become mechanics, are no longer an obstacle.

With this much in a preliminary way I will now notice some matters connected with apprentice experience in the workshop, endeavoring to select such as may be of most value to a learner.

When you enter the shop the first thing to be done is to gain both the confidence and the respect of the manager or foreman who has charge of your work, and remember that to gain this confidence and respect is different from and has nothing to do with your social relations. To inspire the confidence of a friend you must be kind, faithful and honorable, but to command the confidence of a foreman you must be punctual, diligent and intelligent. There is no more kindly

sentiments of regard than those that may be founded in this way, and altogether independent of what is popularly considered as the incentives to such a relation. You may have the misfortune to break tools, spoil your work, and fail in every way to satisfy yourself, yet if you are punctual, diligent, and manifest an interest in the work, these misfortunes will not call out the resentment of those around you.

It must always be remembered that what is to be learned is not in the shop to be estimated according to your own conceptions of its importance. A manager and the men around look upon fitting as one of the most honorable and intelligent of pursuits, and deserving of the esteem and highest efforts of an apprentice; and while the learner may not think it a serious thing to make a bad fit, or to meet with an accident, his estimate is not the one to judge by, and the least word or act that will lead workmen to think that an apprentice is indifferent, from that moment will destroy their interest in him and cut off one of the main sources from which his knowledge is to be derived.

An apprentice should in entering the workshop avoid everything that flavors of fastidiousness, either of manner or of dress; nothing is more repulsive to workmen, and it may be added, nothing is more out of place in a machine shop. An effort to keep as clean as the nature of the work will admit of, is at all times right, but to dress in clothing that is not appropriate, or to allow an aversion to grease to interfere with the performance of work, is sure to provoke derision.

The art of keeping reasonably clean even in the machine shop is worth studying; some men are greased from head to foot in a few hours, no matter what their work may be; while others, except their hands and an apron, will keep clean and perform the same work without sacrificing their convenience in the least.

This is the result of habits that are easily acquired and easily retained, which may become of great use, as well as tend to an economy of clothing, and a neatness of appearance that will convey an impression of neat work.

Be punctual; it costs nothing, and buys a great deal. The learner who reaches the shop a quarter of an hour before starting time, and spends the time in looking about, not only manifests an interest in his work, but avails himself of an important privilege, and one of the most effectual in gaining shop knowledge. Ten minutes spent in

walking about noting the changes wrought in the work from day to day furnishes constant material for thought, and acquaints a learner with many things which he would not otherwise observe. It requires, however, no little care and discrimination to avoid a kind of resentment that any workman feels in having his work examined, especially when he has met with an accident or made a mistake, and when he thinks that the inspection is prompted by curiosity alone. The better plan in such cases is to ask permission in a way that no one will hear it except the person addressed, the application of which will always secure both courtesy and explanation.

Politeness is as indispensable to a learner in a machine shop as it is to a gentleman in society; no matter who the men may be that are to be dealt with, courtesy is not only their due, but the policy for the learner. The character of the courtesy may be modified to suit the person, but still it must be courtesy. The apprentice may understand differential calculus, but a workman may understand how to bore a steam cylinder, and in his estimation the two things are equal, and if he should gain an advantage in politeness, the apprentice is placed at a disadvantage. A man is coarse indeed when he is not influenced by courtesy that is not affected nor overdone.

Questions and answers constitute the greatest means of acquiring technical information, and the engineering apprentice should carefully study the true principles of questions and answers, just as he does the principles of machinery. Without the art of questioning but slow progress will be made in learning shop manipulation, and improper questions will soon lose all the advantages that might be gained.

A proper question is one that the person asked will understand, and the answer be understood when it is given; not an easy rule, but a correct one. The main point is to consider questions before they are asked; let them be relevant to the work in hand, and not too many. To ask frequent questions, is to convey an impression that the answers are not considered, an inference that is certainly a fair one, if the questions relate to a subject that demands attention. If a man is asked one minute what diametrical pitch means, and the next minute how much cast iron shrinks in cooling, he is very apt to be disgusted, and think the second question not worth answering.

It is important, in asking questions, to consider the mood and present occupation of the workman addressed; one question asked

when a man's mind is not occupied, and when he is in a communicative humor, is worth a dozen questions asked when he is engaged, and when he is not disposed to talk.

It is a matter of courtesy in the usages of the shop, and one of expediency with the learner to ask questions from those who are presumed to be best informed on the subject to which the questions relate, and it is equally a matter of courtesy to ask questions of different workmen, being careful, however, never to ask two different persons the same question, nor questions that may call out conflicting answers.

There is not a more generous or kindly feeling in the world than that with which a skilled mechanic will share his knowledge with those who have gained his esteem, and who, he feels, both merit and desire the aid that he can give.

An excellent plan to retain what is learned, is to make notes, not to attempt to store up a book of notes for reference which would not only be of no value but would hinder the memory, but to make notes that may be referred to a few times and to assist in fixing facts in the mind. There is nothing that will assist the memory more in learning mechanics than to write down facts as they are learned, even if the memorandum is never again referred to.

I do not intend to recommend writing down rules, tables that may apply to shop manipulation, but facts that require remark or comment which will not only assist in committing such facts to memory, but will cultivate the power of making technical descriptions, which is a necessary part of an engineering education. Specifications for engineering work are the most difficult of composition; they may be long, tedious and irrelevant, or concise and lucid. There are also a large number of conventional phrases and endless technicalities that must be learned, and to write them will not only assist in committing them to memory, but will determine their orthography.

In making notes, as much as possible of what is written should be condensed into brief formulas, a form of expression that is fast becoming the written language of the machine shop. Reading formulas is in a great degree a matter of habit, like studying mechanical drawings, which, at the beginning, are a maze of complexity, and after a time become intelligible and clear at a glance.

Upon entering the shop, the learner will generally, to use a shop phrase, be introduced to a cold-chisel and a hammer, and he will, per-

haps, regard these hand tools with a kind of contempt. Seeing other operations carried on by power, and the machines in charge of skilled men, he is too apt to esteem chipping and filing as of but little importance, and mainly to keep apprentices employed. Let the apprentice be assured that long after, when a score of years has been added to his experience, the file will still remain the most crucial test of his hand skill, and that after learning to manipulate power-tools of all kinds in the most thorough manner, a few blows with a chipping-hammer, or a half dozen strokes with a file, will not only be a harder test of skill, but the one that he is most likely to meet with.

To learn to chip and file is indispensable, if for no other purpose, to be able to judge of the proficiency of others or to instruct them. Chipping and filing are purely matters of hand-skill that are tedious to learn, but when once acquired, are never forgotten. The action of a file is an interesting problem to study, and one of no little intricacy, as the learner will find when he considers it; in filing across a surface one inch wide, with a file twelve inches long, the varying pressure that is required at each end of the file to guide it level, seems to be beyond the attainment of the hands and beyond the nice sense of feeling that determines this varying pressure. It is quite a problem even if there is a constant length of stroke assumed, but when we consider that the stroke is continually changed, the length of the files and the breadth of the surface also, it is a wonder indeed that true surfaces can be made with a file, or even that a file can be used at all. The fact is, it takes years of experience to file well, and requires also a special faculty which every one does not possess.

In filing, the files should be kept clean, each one laid in order, with a strip of wood under the ends, to prevent them from rolling and to keep them out of the dirt. Each file should have its handle well fitted and to stand true with the blade. The learner has continually to contend with an inclination to use his smooth and dead smooth files before the work is finished, and to think more of the finish on surfaces than their truth.

If asked for advice as to the most important object for an apprentice to aim at in beginning his fitting course, nine out of ten experienced men would say, "to do work well." As power is measured by force and velocity, work is measured by the two conditions of skill and time. The first consideration being, how well a thing may be done, and secondly, in how short a time may it be performed. The

skill spent on a piece of work is the measure of its worth; if work is badly executed, it makes no difference how short the time of performing the task, this can add nothing to its value.

The learner is very apt to reverse this proposition at the beginning, and place the time before the skill, but if he will note what he sees around him it will at once appear that the first criticism is always directed to the character of the work performed. A manager does not ask a workman how long a time was consumed in preparing a piece of work until its character has been passed upon; in short, the quality of work is its mechanical standard, and the time consumed in preparing work is the commercial standard, applied, of course, to work that is good and competent, for if an article is spoiled there is no need of proceeding to the second standard to judge it by. A job is never properly done when the workman can see faults in it, and in machine fitting, as a rule, the best skill that can be applied is no more than the conditions call for, so that the first thing to be learned is to perform work well, and afterwards to perform it rapidly.

Good fitting is not so much a question of skill as of a standard that the workman has fixed in his mind, and to which all that he does will conform. If this standard is one of exactness and precision, all that is performed, whether it be filing, turning, planing or drafting, must come to this standard. This faculty of mind I can define no further than to say that it is an aversion to whatever is imperfect and a love for what is exact and precise, and I must add that there is no faculty of the mind that has so much to do with success in mechanical pursuits, nor is there any trait that is more susceptible of cultivation. Exactness and methodical reasoning are the powers that lead to proficiency in engineering pursuits.

There is, perhaps, no more fitting conclusion to these suggestions for apprentices than a word about health and strength. It was remarked in connection with the subject of drafting that the powers of a mechanical engineer were to be measured by multiplying his education and mental abilities into his vitality and physical strength, a proposition which it will be well for the apprentice to keep in mind, for he will certainly meet with its proof, if not in his own case, in that of others.

An apprentice who is not accustomed to manual labor will after commencing find his limbs aching, his hands sore, and will feel exhausted both at the beginning and at the end of the day's work.

These are not dangerous symptoms. He has only to wait until his system is built up so as to sustain this new draught upon its resources and until nature furnishes a power of endurance which will in the end be a source of pride and add a score of years to his life. Have plenty of sleep, plenty of plain substantial food, keep the skin clean and active, laugh at privations, and cultivate a spirit of self-sacrifice and a pride in endurance that will court the hardest and longest jobs.

An apprentice that has not the spirit and firmness to endure physical labor, and to adapt himself to the conditions of the workshop, should select some pursuit of a less aggressive nature than mechanical engineering.

THE END.

ON THE EFFICIENCY OF BELTS OR STRAPS AS COMMUNICATORS OF WORK.*

By Professor Osborne Reynolds.

It has often been remarked that it seems to be impossible so to construct belts that they shall drive without slipping. I am not aware that any reason has ever been given for this; but, on the other hand, most writers seem to have assumed that if the belt is made sufficiently tight, so that the tension on the slack side is from one-half to one-quarter that on the tight side, according as the strap is in contact with one-half or the whole of the pulleys, it will not slip. The object of this communication is to show that not only is a reason to be given for this residual slipping, but that it follows a definite law, depending on the elasticity of the strap, and independent of its tightness over and above what is necessary to prevent it slipping bodily round the wheel.

When a pulley, A, is connected with another pulley, B, by a belt so that A drives B, it is usual to assume that the surfaces of the two pulleys move with the same velocity, namely, the velocity of the strap; and that the work communicated from A to B equals this velocity multiplied by the difference in the tension on the two sides of the belt.

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* Reprinted from the London *Engineer*.

This law would doubtless be true if the strap were inelastic, and did not stretch at all under the tension to which it is subjected; but as all straps are more or less elastic, it can be shown that this law does not hold rigorously; although with such an inelastic material as leather it is not far from the truth.

Owing to its elasticity, the tight side of the belt will be more stretched than the slack or slacker side, and will, in consequence, have to move faster. This is easily seen when we consider that each point on the strap completes its entire circuit in the same time, so that if at any instant a number of marks were made on the strap at different points, these marks would all return to the same points in precisely the same time; for the velocity at each point would be equal to the length of strap which passes that point, and on the tight side this would be the stretched length, whereas on the other side it would be the unstretched length, and hence the two sides of the strap would move with different velocities, according to the degree in which the strap is more stretched on the one side than on the other.

Now the stretching of a strap will be proportional to tension, although the degree will depend on its size and the material of which the strap is composed. Let $\lambda\, \tau$ represent the increase in length per foot in a certain strap, caused by a tension of τ lbs. Then, if τ_1 and τ_2 represent the tension on the two sides of the belt respectively, the stretching on these two sides will be respectively proportioned to $\lambda\, \tau_1$ and $\lambda\, \tau_2$, and the difference will be proportional to $\lambda\, (\tau_1 - \tau_2)$. Therefore the velocities of the two sides will be in the ratio $= \dfrac{1 + \lambda\, (\tau_1 - \tau_2)}{1}$.

Again, it is easy to see that the velocity of the tight side of the strap must be equal to that of the surface of the pulley A which drives it; whereas the velocity of the pulley B, which is driven by the strap, will be the same as that of the slack side of the strap; and hence the velocities of the two pulleys differ in the ratio $\dfrac{1 + \lambda\, (\tau_1 - \tau_2)}{1}$.

And since the turning effort of the strap on either pulley is the same, namely, $\tau_1 - \tau_2$, the difference of its tensions, the work done by A, which equals its velocity into this effort, will be greater than that taken up by B in the ratio $\dfrac{1 + \lambda\, (\tau_1 - \tau_2)}{1}$. This excess of work will have been spent in the slipping, or more properly the creeping, of

the strap round the pulleys. The manner in which this creeping takes place is easily seen, as follows: The strap comes on to A tight and stretched, and leaves it unstretched. It has therefore contracted while on the pulley. This contraction takes place gradually from the point at which it comes on to that at which it leaves, and the result is that the strap is continually slipping over the pulley to the point at which it first comes on. In the same way with B; the strap comes on unstretched and leaves it stretched, and has expanded while on the wheel, which expansion takes place gradually from the point at which the strap comes on until it leaves.

The proportion which the slipping bears to the whole distance traveled by the strap $= \lambda (\tau_1 - \tau_2)$, which, as previously shown, is the proportion which the work lost bears to the whole work done by A. From this it appears that the slipping and work lost are proportional to λ, *i. e.*, to the increase which a tension of 1 lb. would cost in 1 ft. length of the strap; and hence, the more inelastic the material is, the better it is suited for belts.

The actual amount of this slipping may be calculated when we know the elasticity of the belts. With leather it is very small. One belt, which had been in use about two years, and was 1·25 in. wide and 3-16 in. thick—the usual thickness—increased in length by sixteen-thousandths under a tension of 100 lbs. From this example it appears that, for a leather belt of breadth b in.:

$$\lambda = \frac{20}{100,000} \frac{1}{b}$$

Hence, the ratio of slipping $= \cdot 0002 \frac{1}{b} (\tau_1 - \tau_2)$; and in practice $\tau_1 - \tau_2$ varies from 20 lbs. to 60 lbs. per inch width of belt; therefore the slipping $= \cdot 008$, or nearly 1 per cent. With new straps it would probably be more. With soft, elastic materials, such as india-rubber, the slipping is very much greater. In some instances I have been able to make the driving pulley A turn twice as fast as the pulley B, simply in virtue of this expanding and contracting on the pulleys. This shows at once how it is that elastic straps, such as can be made of soft india-rubber, have never come into use—a fact which is otherwise somewhat astonishing, considering for how many purposes an elastic connection of this sort would be useful. A similar explanation to the above may also be given for the friction occurring

when elastic tires are used for the wheels of carriages and engines. The tire is perpetually expanding between the wheel and the ground. As the wheel rolls on to the tire, it is continually elongating the part between it and the ground which is in front of the point in which the pressure is greatest. This elongation can only be accomplished by sliding the tire over both the surface of the wheel and the ground against whatever friction there may be; and similarly, towards the back of the wheel, the tire is contracting also against friction. Even when there is no tire, if either the wheel or the ground is elastic a similar action takes place; and hence we may probably explain what is usually called rolling friction, which has been observed to take place, no matter how true or hard the surface of the wheel and the plane on which it rolls may be. *Owens College, Manchester, Nov.* 20, 1874.

Development of Magnetism in the Rails of Railways.—M. Heyl, engineer of one of the German railways, in a recent report upon the special section under his charge, calls attention to the development of magnetism in the rails. He says: I have observed that all the rails are transformed at their extremities, after they have been placed in position a few days, into powerful magnets, capable of attracting and of retaining a key or even a heavier piece of metallic iron. These rails preserve their magnetism even after they have been removed, but they lose it gradually. When in position, however, the magnetism is latent, only becoming free when the chairs are removed and disappearing again when they are replaced. Hence it is necessary to assume that two opposite poles come together at each junction, and that each rail is a magnet, the poles being alternately reversed throughout the line. This production of magnetism in the rails examined is undoubtedly attributable to the running of the trains and to the shocks, frictions, etc., thereby produced. The hypothesis of electric currents, induced or direct, must be rejected, since it is negatived by experiments upon the subject made with suitable apparatus. Although the interest attaching to the fact above stated is at present purely scientific, it is not impossible that the magnetism thus developed may exercise an influence actually beneficial upon the stability of the roadway, increasing the adherence to the rails and the friction. It is possible, also, that the magnetic currents may be stronger at the moment of the passage of the trains, than either before or after. If this be so, the observations may acquire a still higher practical importance.

Chemistry, Physics, Technology, etc.

NEW PROCESSES IN PROXIMATE GAS-ANALYSIS.

By Professor Henry Wurtz, of New York.

[*Communicated in part, with Experimental Illustrations, to the American Gas-Light Association, October* 22, 1874.]

Gas-analysis, in the widest and highest sense of the expression, comprehending the proximate analysis of gaseous mixtures, natural and artificial, as well as the ultimate analysis of gaseous compounds, includes what have heretofore been unquestionably the most difficult and delicate, while also, when correctly viewed, the most fruitful and promising branches of laboratory chemistry. It is also quite just to assert of these branches that they have of late years been far too little cultivated by many chemists of the first rank. It is to this that I would attribute the fact that your own great and noble art of Artificial Illumination—to which I might add those of metallurgy and furnace operations generally—linger in a stage of empiricism not in accordance with the actual advancement of chemical science. It may safely be alleged that we are now learning far more, and more rapidly, of the liquid and solid products of retorts, stills and furnaces, than of the gaseous products. This should not continue; and I venture to hope that the observations I have to offer may in some measure lead the way, and to some extent lay the foundation for the more diligent application of known chemical principles to the practical investigation of gaseous mixtures and products of the chemical arts.

The class of methods known by the rather insignificant name of Eudiometry, had so great an impulse imparted to it a quarter of a century ago by the genius of the illustrious Bunsen, that gas-chemists have really seemed to me to merit since, in some measure, the reproaches cast upon the immediate disciples of Aristotle of old, who believed their great master had probed the depths of possible human wisdom, and therefore refused to interrogate Nature further. It is

true that many of Bunsen's methods, apparatus and manipulations in gas-analysis will remain indispensable, and will stand as monuments to his fame, very little having been done since except in the way of modification, by other chemists; but there are nevertheless cases and conditions often of great importance, where all so-called eudiometric methods fail to satisfy the practical requirements.

One such case may here be entered into as an example. This is the determination of *air*, as a contamination of illuminating gas. It is well understood that each single proportion per 100, of air, destroys at least six per cent. of the illuminating value of an ordinary coal-gas. It is not easy then to exaggerate the importance of this case. But, in a eudiometer 500 millimeters long, one volume per 100 of air is but one millimeter of oxygen. A variation or error of observation of a single degree Fahr. of temperature, or of ·061 inch of barometer, down or up, will either double or destroy this determination. But by the methods I have now to propose, one cubic foot of such gas will yield, in a form amenable to the balance, 1·18 grain = ·076 gram of oxygen; and 5 cubic feet, ·3815 gram.

Moreover, in eudiometric oxymetry, the introduction of potassic pyrogallol into the gas under investigation, is always of necessity preceded by that of potassic liquor or potassic hydrate, to remove carbonic acid; and if this potash be washed out with water, say with a minimum, of 20 millimeters (in a eudiometer of 500 mm.), of the latter, this water will always abstract some of the oxygen sought to be determined. At 60°F. = 16°C., 20 mm. water can take up (Bunsen) ·59 mm. of O; or, in this way, as much as 59 per cent. of the oxygen (and air) sought may be altogether lost! I may add that, in working on coal-gas, the further possible, or at least supposable absorption, by this 20 mm. water, of ·29 mm. of N, ·39 mm. of H, and .48 mm. of CO gases—together with the ·59 mm. of O—1·75 mm. in all—might vitiate the CO^2 determination to the extent of 0.35 per cent. of the whole volume, in excess; which, in a coal-gas purified by lime, would be a vitiation quite fatal to the value of the analysis.

Some eudiometrists may reply that they do not wash out the potash with the water, before applying pyrogallol. If so, I must impugn their work on several other grounds:—for instance, will the film of potash liquor on the inner walls of the eudiometer occupy the same volume as a film of pure water? My own experiments have shown me that it will not. Again, either solid potash or strong potash liquor

desiccates the gas, thus introducing another very appreciable error. A conscientious original investigator who tests all methods rigidly himself, will devise ways to mitigate, if not to eliminate some of these difficulties; but this does not meet the practical requirements of the case, for all are not competent to do this.

The above is cited as but one sample of the multitude of difficulties with which every really competent eudiometrist must admit himself to be environed.* Special and complex devices have not been wanting —many of them of great and permanent value—to lessen certain difficulties; but it has appeared to me that in those cases—including many of the most important ones, as, for example, illuminating gases and gaseous furnace-products—in which the mixture to be analyzed is attainable in volumes practically illimitable; it would be well to try to cut loose from methods which are purely volumetric, and to devise such new ones as would enable us to deal with quantities that can yield ponderable products; thus appealing directly to that infallible criterion, the chemist's "court of last resort," the balance.

In this attempt, I have already met with success sufficient to encourage me to place the results before the chemical world, confident that some things will be recognized in them worthy at least of being followed up and brought to a further stage of perfection. This further pursuit of these paths of promise will be my own task so far as it may be permitted to me.

The methods I now put forth are founded on the general principle of submitting a slow current of the gas to be investigated to the action of a series of agents, so selected and combined as to absorb and separate, in succession, each by itself, the different proximate constitutents of a gaseous mixture, converting each into a solid or a liquid form, which can be weighed on a balance. About 1840, European chemists were using successfully methods of this class. One method, which arose at that time out of their experiments in this direction, was that still in use in "Organic Analysis," for separating

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*I may be excused for here introducing the remark that I myself have endeavored to do my share with other gas chemists towards the emendation of Bunsen's system of eudiometry. My own efforts have been generally in the direction of simplification, acceleration, and more especially to attain (what I have always deemed) the great desideratum of a reduction of the needful amount of quicksilver to a minimum. I now use simple devices and manipulations which enable me to accomplish all the essential work of eudiometry with at the most 10 lbs., and chiefly with not more than 5 lbs. of the liquid metal. These will soon be submitted to the chemical world.—H. W.

in distinct and weighable forms water and carbonic acid. Strangely, however, the capabilities of these methods seem to have been looked upon as very narrow and special, and they have passed almost out of view. At the present day it is probable that a majority of chemists would not have anticipated, in advance, much satisfactory success in the application of these modes of procedure to such complex mixtures as crude coal-gas, or a furnace-gas. My experience has, nevertheless, tended to an opposite conclusion, and I believe that I discern, in this direction, the only practicable road to complete success in the proximate analysis of heterogeneous gases.

[In this memoir, I will here say, I must confine myself mainly to illuminating gases. The handling of furnace-products by these methods will furnish subjects for future communications.]

In a crude coal-gas, as drawn from the hydraulic main, over the retort benches, the following main constituents may be enumerated, which it is highly important that a gas-chemist should be competent to separate and determine with precision:

1. Tar, suspended in the form of spray.
2. Water, in similar mechanical admixture.
3. Water, as vapor, dissolved in the gas.
4. Naphthaline (condensable).
5. Other condensable hydrocarbons.
6. Smoke and soot (with dust).
7. Ammonia.
8. Carbonic Acid.
9. Sulphuretted Hydrogen.
10. Carbonic Oxide.
11. Oxygen, that is, Intermixed Air.

Of these eleven proximate constituents I have so far succeeded in separating, with very satisfactory sharpness, Nos. 1, 2, 3, 6, 7, 8, 9, and 11; eight in all, besides some approximation to No. 4, the naphthaline in excess. Nos. 5 and 10 are still subjects of experiment.

My success so far is to be attributed mainly to the gradual attainment and combination, by tentative experiment, of the following devices and manipulations.

First—Arresting suspended matter by means of empty dry flasks and straining through cotton previously *desiccated.*

Absorbing next, the ammonia, by means of reagents which act on no other ingredient.

Next, drying the gas with calcium chloride, which, ammonia being absent, may now be done.

Next, taking up the sulphuretted hydrogen by a normal metallic salt, so selected or so managed as to give up no water or acid vapor to the desiccated gas.

Next using sodic hydrate to absorb the carbonic acid, with certain precautions described below.

Next, alkalized pyrogallol or other suitable agent, to absorb oxygen, arranged so as to lose no water.

In the case of illuminating gases—with some few others—the final (rough) measurement of the gas is then made at an observed temperature by a gas meter; if with a dry meter, directly; if with a wet meter, after saturation with moisture at the temperature of melting ice.

In the latter case, of a wet meter, the amount of final moisture in the gas is determined by a reiterated desiccation with calcium chloride.

The whole process is finally completed and the separations rendered as sharp as may be, by a process of distillation, either at the ordinary or higher temperature in a current of the same gas analyzed, that has been previously subjected to the same or similar treatment and thus freed from all the ingredients to be separated from each other.

After final weighings, the *correct* initial volume of the gaseous mixture is calculated by certain formulæ derived, as specified below, from the crude meter-indications and the final weighings.

I shall now proceed to an attempt to explain (simultaneously to save space) the details of the methods as applied to each constituent, and those of the construction, preparation, and arrangement of the different pieces of apparatus, as connected and represented in the figures.

I. Analysis of Crude Gas, in the Gas-House, before Purification.

The mechanically suspended Tar and Water. The joint devices for arresting these two substances, in the first instance, are shown in Fig. 1, letters A to F inclusive. A indicates an inch-thick soft-rubber cork, with two perforations, occupied respectively by a thermometer and an eduction-tube bent at a right angle, inserted into an aperture bored through the wall of the hydraulic main or of any other main in the works. This eduction-tube must at once descend, to

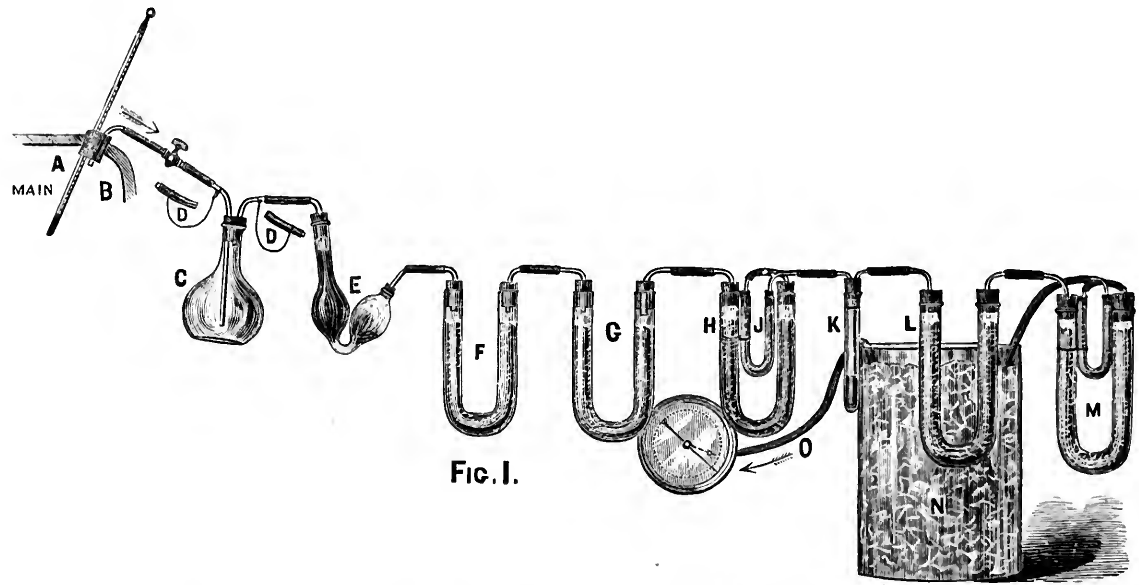


FIG. I.

TRAIN FOR THE ANALYSIS OF CRUDE MIXED GASES: FROM THE HYDRAULIC MAIN OF A GAS WORKS, ETC.

[NOTE.—Between G and H an additional tube, precisely similar to G, charged with *chloride of calcium*, is employed, which for simplification, has been omitted from the figure.]

allow liquids to flow into the flask, and must have a stop-cock in it. The first member of the train is an empty dry thin glass flask C, which collects almost the whole of the spray, aqueous and tarry. DD are two stoppers for closing C hermetically, constructed of pieces of rubber tube closed at one end by short sections of glass rod. The bent wires by which these are permanently attached to the flask had better be of iron than of copper, as they are to be weighed with the flask, and the latter metal is quickly blackened and may be slightly changed in weight by the sulphide of ammonium that pervades the atmosphere of the gas-house. In a permanent apparatus, for nicety, platinum wires had better be used. Copper wires, however, used here, and in other parts of the apparatus, may be protected pretty well by coating with collodion, or even with a film of paraffine. [All the brass stop-cocks I use in these and all other operations with sulphuretted gases, I prefer to plate, inside and out, with nickel, which protects them perfectly against sulphur. This nickel-plating every gas-chemist will find it well worth his while to perform for himself, as it is *very* easy to accomplish, in case of brass and copper surfaces, with slight practice. I propose publishing a note which I think will lead any laboratory worker to success in his first trials.]

These trains of apparatus are probably most conveniently set up by being suspended to a strong wire—best of soft copper—stretched tightly between two convenient points of attachment. To make this wire tense or "taut," it had better be in two pieces, attached first at the extremities, then twisted together strongly and warily with pincers at the point of meeting. The tubes are hung on inverted V-shaped (Λ) wires bent into hooks below. These, for simplicity, are not figured. All the rubber tubing used as connectors, I wash laboriously, internally and externally, in a rapid current of water with hard rubbing between the hands, until absolutely clean, then rub dry, and lubricate, within and without, with thick syrupy glycerin. The excess of this being wiped off, the tubing is found permanently more flexible, far less liable to abrasion of surface, more easily slipped over ends of glass tubing, and, above all, has its capacity for absorbing certain constituents of the gas reduced to a minimum. All the corks should be rubber, scoured and glycerated superficially in the same way. The cork at A—owing to the heat and actual contact with tar—and, to a less extent, the cork of flask C, are somewhat penetrated and soft-

ened, so that A gives out, after being used a number of times. The others last indefinitely.*

E and F are stuffed, uniformly, but as loosely as practicable, with cotton, which is best inserted and gently packed down, in successive small wads, picked out before insertion. The bulbous pattern, like E,† may present here some advantage, but it is not at all essential. Its use, as photographed in this case, was in order to bring down somewhat the level of the rest of the train. I have used, and prefer, a compound cotton apparatus, or two tubes of the size of F, united by a twisted wire in the manner of A in Fig. 4. These can be weighed together conveniently.

Even in case of a gas that has passed through condensers and scrubbers, it seems necessary to use two tubes of cotton. In one actual series of analyses, of unpurified coal-gas before and after having passed the scrubbers and condensers, the second tube F, increased, on an average, in weight (all moisture having been removed) from the uncondensed gas ·128 grain, and from the condensed ·072 grain, per cubic foot of gas passed, up to 7 cubic feet. The main consideration here is the initial *pressure* at command, of the gas. If the customary exhauster is employed in the gas-works, and kept at work during the analyses, the pressure between the exhauster and the retorts may be found so low that a train attached between these, may not admit of more than one cotton tube, and even this packed as loosely as possible. At points beyond the exhauster, however, this trouble seldom occurs; it having been necessary indeed, in some such cases, with unpurified gas, to partially close the cock in the eduction tube, to bring down the rate of flow through the train to about one cubic foot per hour, which it should not in most cases exceed.

The Ammonia.—In order that we may employ, for dehydration, the highly convenient, powerful, and reliable agent, chloride of calcium, it quickly became apparent to me, in my earliest experiments, that the ammonia must first be abstracted from the gas; and my first efforts were to decide upon the proper agents that could be used,

* All these corks should be of the *best* quality made. Many in the American market are very poor—indeed, useless, for this kind of work.

† I may say here that E, as shown in the cuts, was in the condition left after having been used, and in drawing from the photograph, an attempt has been made, none too successfully, to reproduce the shading of the arrested soot.

in solid form, for this absorption. One of these I have sufficiently tested, by quantitative as well as qualitative experiments, to demonstrate its entire applicability to this use; namely, fused *potassic bisulphate.* It is proper for me here to state that the earliest preliminary experiments with the bisulphate, were made, at my suggestion, in the course of an investigation carried on jointly by Prof. B. Silliman,* Dr. S. D. Hayes and myself; in which we desired to absorb the ammonia of crude coal-gas. We all became convinced, I believe, that potassic bisulphate had the power to take out *qualitatively* the NH^3 from gas; but the precautions essential to success, in a quantitative way, have been since worked out by myself alone.

The mode of preparation of the bisulphate is by simply cracking in a mortar to the average size of wheat-grains, and removing the dust and finer particles by a sieve of eight holes to the inch. The dust is very painfully irritating and injurious, and its inhalation must be avoided, if possible.

[Though many chemists seem somehow to have acquired the idea that bisulphate of potash possesses more or less *deliquescence*, it in reality has none of this quality whatever, and it is not even hygroscopic, to any remarkable extent.]

It must not be supposed that the bisulphate takes up ammonia as NH^3, which would involve a very important error. The compound formed, as desiccated for the final weighing, is the double sulphate of potash and oxide of ammonium. The factor *am* in the equations below must be obtained, from the increase of weight, by multiplying by a coefficient = ·70833. And it may here be remarked that a part of another factor *wv* comes likewise from this increase of weight, through multiplying it by ·29267. This ammonia-tube is lettered G.

The Water.—Chliorde of calcium for absorbing this, comes next in our Fig. 1 train, though, as it would be merely a duplicate of G. the CaCl tube has been omitted from the cut. I prefer, after trying many preparations—a *fused* chloride, assuring myself, above all, that it is free from every trace of causticity, and crack it up to the size of small peas, sifting out all that passes a sieve of six holes to the inch.

* Prof. Silliman has also since worked by himself on this or a closely related subject, and made a communication to the National Academy, at the late Philadelphia meeting, to which I would refer. Prof. S., I believe, experimented chiefly on the utilization of crude commercial bisulphates, generally of soda, called "salt cake" in commerce; for the technical extraction of ammonia from gas.

For the small CaCl-tube J, the one in M (Fig. 1), and J and L in Fig. 4, I find it desirable to crack but little, if any, smaller; to avoid risk of obstruction.

The Sulphuretted Hydrogen.—For this constituent I have tried several absorbents, but none as yet that answers, on the whole, so well as common crystallized blue vitriol, cracked and sieved to wheat-grain size. As in desiccated air it slowly loses some of its water (Graham found that in fine powder, over oil of vitriol, it lost in seven days 3 of its 5 water-equivalents) I add a small calcium chloride tube, which is of course weighed with it in all cases. The test-tube K, containing a slip of lead-paper belongs (qualitatively) with the cupric-sulphate tube H.

With crude gas from highly sulphurous coals it may sometimes be prudent to duplicate this member of the train. Of course the small CaCl tube J need be added only to the second one. The increase of weight in this member is of course HS. If to be calculated as simple sulphur, as sometimes required, it must be multiplied by ·9471.

The Carbonic Acid.—The agent which combines, for this absorption, the greatest advantages by far, is that form of sodic hydrate now so common in commerce, cast into pencils, and labeled "soda by lime." In this class of operations the weight of CO^2 to be absorbed is often very large. In ten cubic feet of crude coal-gas containing 2 per cent. by volume of CO^2, there is about 172 grains by weight of the latter, which requires for absorption (if normal carbonate be formed) near 315 grains of sodic hydrate. Although some bicarbonate is usually formed, yet the absorbing surface required is large. Potassic hydrate, prescribed in the books, is wholly out of the question for these methods. The solubility of KO,CO^2 is so great, especially as much heat is always developed during the CO^2 absorption, that the water of the hydrate serves to melt the mass into a magma and quickly to obstruct the flow. In cases where mere abstraction of CO^2, without weighing, is the object, one large tube containing 10 or 12 ounces of sodic hydrate—as in H, Figs. 2 and 3—may be employed; but in the case under consideration, two tubes must be used, containing each 5 or 6 ounces, to reduce within conveniently weighable limits. These are here lettered L and M.

(To be continued.)

DILATATION OF CAST IRON AND THE PHENOMENA OF THE CRANE LADLE.*

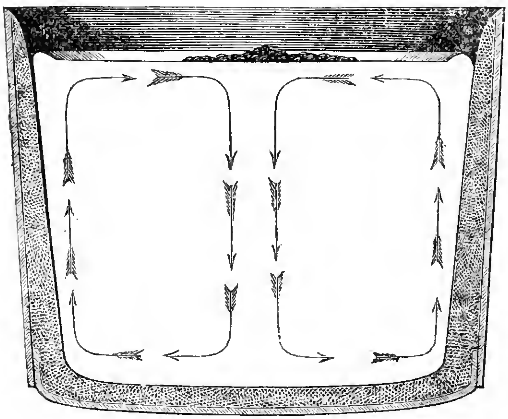
By Robert Mallet, C. E., F. R. S., etc.

In my former paper on this subject—*The Engineer*, Sept. 11th—the linear dilatation of bright gray cast iron between 60° Fahr. and 2400°, the assumed temperature at which such liquid cast iron is usually poured into moulds, was deduced as equal to 0·02606 of the unit length. The temperature at which the iron is poured is, however, necessarily above the melting point, and in my experiments this excess may be estimated at 200° Fahr., deducting which from the total range of temperature of my experiments, viz., 2400°—60°, gives for the entire range of temperature between 60° and the melting point = 2140°, the total dilatation corresponding to which is therefore 0·0234, which is approximately equal to 9-32 in. per foot in length. The average allowance made by pattern makers for "shrinkage," deduced from long experience, varies from 4-32 in. to 6-32 in. per foot in length of the pattern, and with some highly contractile cast irons—such as the No. 3 Blaenavon pig, much used for engineering castings some years ago—to about 8-32 in. The actual dilatation as thus determined experimentally exceeds the excess in dimensions given to patterns in accordance with the empiric rules of pattern makers; but the linear dimensions of the sand mould are not determined by those of the pattern alone, but exceed these by the amount of "rapping" or shaking in the sand necessary to free the pattern, and enable it to be "drawn" therefrom. The mould thus exceeds the dimensions of the pattern by an uncertain and variable linear amount, varying with the absolute size and form of the pattern, the delicacy of manipulation of the workman and other circumstances. And as we see the enlargement of the mould produced by this "rapping" may amount to almost as much again as the excess in dimensions which the pattern maker allows in the pattern, we may thus readily observe the futility of the statement made in many works on metallurgy that the pattern makers' allowance for "shrinkage" affords a criterion for fixing the total dilatation of cast iron. Although I

* Reprinted from the London *Engineer*.

have been thus enabled to determine experimentally for the first time the actual dilatation of that most valuable variety of cast irons, namely, that close bright gray iron employed by engineers for structures and machinery, much more remains to be done, and I hope will be done, by other experimenters before the subject can be considered as complete. The total dilatation of white crystallized cast iron, and of the very soft large grained and almost black cast iron which occupy the two extremes as to dilatation, remain yet to be experimentally determined, as well as the effects of very rapid or very slow cooling upon the same cast iron. These did not come within the scope of my own inquiry, which was limited to proving that liquid cast iron is not more but less dense than the same cast iron in the solid state and at atmospheric temperature, contrary to the views often expressed, and prominently so, by Messrs. Nasmyth and Carpenter in their work upon the moon. In support of their views two different sets of collateral facts have been appealed to, namely, first, the notion that the perfection with which cast iron adapts itself to the form of the mould arises from its assumed expansion in volume at the moment of consolidation or "setting." This I have treated of in my last communication—*The Engineer*, 11th inst.—and shown that there are sufficient reasons why cast iron affords such perfect castings, irrespective of any delusive appeal to such expansion in volume, which has been proved not to have any existence. Secondly, another class of facts, viz., those presented by the circulatory movements noticeable in large masses of liquid cast iron, have been appealed to in support of the erroneous notion of the increase in density in cast iron with increase of temperature above the melting point. When a large, clean and newly-lined crane ladle, containing eight or ten tons, is filled from the furnace, and left to repose, circulatory currents may be observed to set in more or less energetically in the liquid metal. It is scarcely necessary to state in *The Engineer* that the crane ladle is a nearly cylindrical vessel, with a flat or slightly convex bottom formed of thick boiler-plate, and that it is lined in the inside with plastic clay and sand mixed with other materials and dried perfectly, so as to form a badly conducting stratum between the iron of the ladle and the mass of molten metal which it holds, the exposed surface of the lining being usually black-washed with powdered coal and water. When the directions of the currents in such a ladle are observed, it is

found that they move upwards about the exterior or sides of the metal, that at the surface they pass inwards convergingly towards the centre, and may be inferred thence to descend about the central portions of the liquid mass, and arriving at bottom of the ladle, pass outwards divergently, to be again carried upwards at the sides—these directions being such as are shown by the arrows on the adjacent figure, which is nearly similar to that given by Mr. Nasmyth in the



work above mentioned. These circulatory currents are attributed by him to the cooling of the mass, and on this assumption he correctly argues that as the cooling takes place chiefly from the bottom and sides of the ladle by radiation and by evecting currents of air, and as the currents are upwards at the sides of the ladle where the iron is coldest, so the specific gravity of the iron thereabouts must be less than that of the hotter central parts of the mass, whence he concludes that the cast iron itself dilates as it cools in place of contracting, for if it contracted the currents must be in the reverse directions to those indicated by the arrows in the figure. No fault whatever can be found with this reasoning, provided we admit the assumption upon which it rests, namely, that the currents observed are produced by cooling alone, that is by the difference in temperature at any moment between the circumferential and the central portions of the liquid mass. In a paper on this subject read before the Royal Society last session, and which will be published probably about the end of this year, I have pointed out that, considering the density and viscosity

of liquid cast iron, and the small amount of its contraction per degree Fahr., no such currents as are observed in large crane ladles could be produced by cooling at the rate at which that actually proceeds in such masses. The currents, however, are there, and usually in the directions shown in the above figure. From what, then, do they arise, if not from cooling? They really originate in the ascending current of gases and vapor given forth by the material of the lining when exposed to the high temperature of the liquid metal. The clay and sand are mixed sometimes with pulverized coke and with chaff or plasterers' cowhair, or other fibrous matter, to give it coherence before being dried, and sufficient openness of texture not to blister or split off or part from the ladle when suddenly heated. All the materials of the lining, therefore, except occasionally the sand, evolve torrents of gases and vapors as soon as the lining is exposed to the roasting contact with the liquid metal. Clays, which are natural hydrous silicates, and contain mechanically suspended as well as chemically combined water, when exposed to a bright red heat evolve these as highly heated steam. The coal wash, the coke dust, and the organic matters present, are more or less rapidly torrefied and converted into carbonic oxide and acid, vapor of water, and several other volatile vapors or gases. Innumerable streams of these are evolved and stream up through the liquid metal most rapidly and copiously where that is in contact with the largest proportionate surface of the lining, giving rise to the ascending currents at the sides of the ladle as seen in the figure, and the upward movement of which necessarily results in the creation of the convergent surface, the descending central, and the divergent bottom currents. That this is the true solution of the production of these currents is conclusively shown by the following facts. Large ladles are usually lined afresh every time they are used; if, as often happens, the metal filling such a ladle be tapped at too high a temperature, and be let to repose for a considerable time until its temperature be suitable for the purposes of the founder, it may be observed that the energy of these circulatory currents sensibly diminishes, so that in a ladle of eight or ten tons they almost cease to be observable, and in much smaller ladles may be occasionally seen to be reversed in direction though with enfeebled energy. It occasionally happens, however, that a large crane ladle is required to be filled with metal a second time before the lining has ceased to be hot. In this case almost no currents are produced, and such as may be remarked

are not in the directions shown in the figure. The volatile matters contained in the lining material having been by the double heating completely driven off, the ascending circumferential currents cease to be produced. The phenomena of the crane ladle, therefore, when rightly interpreted, present no corroboration whatever of the erroneous supposition that cast iron becomes denser as its temperature above its melting point is higher. It is to the nature of the gases and vapors generated from the materials of the lining, and chemically reacting upon the liquid iron as they stream up through it, as well as to the action of the atmosphere upon the constituents of the cast iron itself at the surface of the molten mass, that are to be ascribed those curious starting and vermicular movements visible upon the surface of a ladle of liquid iron, and known amongst founders as the "breaking" of the metal. The vapor of water as it streams upwards is partially decomposed, and its oxygen oxydates some portions of the cast iron while its hydrogen deoxydates others. The gases generated from the organic materials present produce like reactions. At the surface of the molten metal the oxygen of the atmosphere oxidates some of the silicon present, producing a film of silicic acid which rapidly combines with the oxide of iron or of other metals also on the surface, producing thus continually a pellicle of fused silicate of iron which breaks and aggregates itself to any little globular particles of slag or silicate already formed and floating on the surface; and as in numerous other examples where opposite chemical reactions are going on at different points in the same liquid mass as here, oxidation and deoxidation, those starting movements are visible which are the indications of sudden overthrows of chemical equilibrium.

This is but a very brief sketch of the causes of those curious movements seen in the "breaking" of cast iron, and in many other metals having high melting points and of ready oxidation and reduction which have been long observed, but not, that I am aware of, previously been attempted to be explained. They present many points of high interest to the chemist and molecular physicist, and present a fertile field for fuller investigation, but the subject is of theoretic rather than of direct practical importance.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

Vol. LXIX. MARCH, 1875. No. 3.

EDITORIAL.

ITEMS AND NOVELTIES.

Tank for Continuously Measuring Feed Water.—We herewith present illustrations of the tank used during the experiments with the U. S. coast survey steamer "Bache," set forth in the report of consulting engineer Chas. E. Emery, published in the February number of this Journal. An almost identical system was adopted in the experiments with the U. S. revenue steamers, as set forth in the report of chief engineer Loring, U. S. N., and consulting engineer Emery, which appears in the present number.*

Figure 1 is a side elevation, and Figure 2, a plan of the tank which is shown erected on blocks of wood. The tank is divided into two parts by a central partition (B) of less height than the outer walls. During the experiments the tank was placed on the main deck, in the gangway abreast of the engine, and the feed water delivered to the same directly by the air pump, through a pipe with a flexible termination (C), which could be directed over either compartment (A, A′) of tank. A pipe (E) with two branches (G, G′) and regulating cock (D, D′) in each, conducted the water from the two compartments re-

*Further explanation will be found in the reports referred to.

spectively, to a tank in the hold, from which the water was withdrawn by the engine feed pumps.

Fig. 1

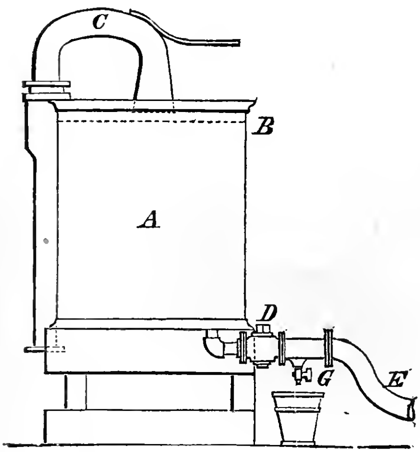
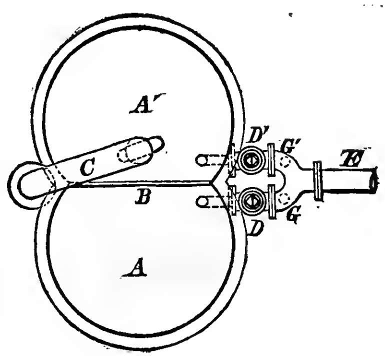


Fig. 2.



The measurement was made by filling one compartment (A), for instance, till it over-flowed into the other (A′), which had been previously emptied; the supply was then changed to the latter (A′), and when the surplus water in first (A) had run off, that compartment was emptied and cock on bottom of same closed in time to receive the overflow from the other (A′); the operation being repeated alternately with each compartment.

New Nut-Locking Washer.—At a recent meeting of the Institute, the Secretary described the device herewith illustrated, which was presented for exhibition by George H. Ball, Esq., of Mount Holly, N. J. The invention is known as Winslow's Improved Nut-Locking Washer, for fish-plate bolts, railroad trucks, etc., and its features will be apparent from the following description:

FIG. 1

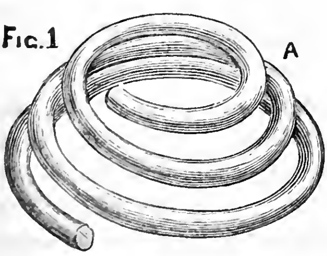
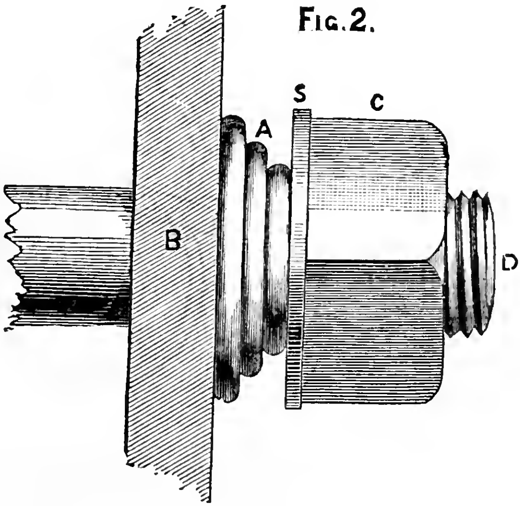


Figure 1 represents a volute conical spring, formed of spring wire, which is placed on the bolt with its base against the fish-plate, followed by a friction washer, and both brought to their places by turning the holding nut up firmly against them, as shown in Figure 2, in

which the nut C, friction-washer S, spring A, and fish-plate B, are shown in position on the bolt D.

FIG. 2.



It is claimed for the device, that the spring, by its considerable resisting force against the holding nut, prevents any loosening of the same, in consequence of the vibration to which it will be exposed when in use. W.

Centennial Exhibition.—As but a little more than a year now remains before the opening of the Exhibition an increased interest is manifested in the preparations, and a desire to know what progress is being made on the different buildings.

With the view of furnishing information on this subject the following particulars have been obtained from official sources:

The art building is from designs by Mr. H. J. Schwarzmann, and the contract was let to Mr. Dobbins, last summer, to be finished by January 1st, 1876.

At first there was some apprehension in the public mind as to the ability to complete it by that time, owing to the supposed difficulties of obtaining the materials in season, and especially the granite. A large portion of this is now delivered on the ground, and the quantity now at sea and ready for shipment at the quarries warrants the belief that all will be delivered by May 1st.

The brick work of the interior walls has reached a height of about fifty feet, and the setting of the granite is well started. The iron work is being pushed forward in the shops, and all other materials are fully provided for.

The preparations of Mr. Dobbins for setting the stone and iron work (including eight traveling steam cranes, derricks, etc.) have been most ample, and will insure the rapid progress of this portion of the work.

In view of all these facts the contractor is quite confident that he will be able to complete the building before the time specified in his contract. As the work progresses it meets the expectations of those who advocated this particular design, and the favor with which it has been received in foreign countries (where it has been largely published) is very gratifying.

The main building, which will be 1880 feet long by 464 in width, is also under contract to Mr. Dobbins, and, as in the case of the art building, his preparations are of the most ample character.

The ground is graded, the foundation piers (about 700) are nearly all built to the surface ready to receive the superstructure, and the work has been delayed only by the unprecedented severity of the winter. Three railroad tracks have been laid the full length of this building, which will greatly facilitate the delivery of material on the spot.

The iron has been rolled and fitted, and is now ready for delivery on the grounds. The erection will commence as soon as the weather permits, certainly not later than April 1st.

The contract for this building also requires it to be finished by January 1st next, but as the preparations are so well advanced, and as the finishing can be proceeded with in part as soon as a portion of the frame work is up, it is not improbable that it will be completed two months sooner.

The machinery building is from designs by and its erection is in charge of Messrs. Pettit & Wilson, engineers and architects to the Board of Finance. It will consist of five principal avenues, two of 90 feet and three of 60 feet in width, parallel to each other, and crossed with a central transept.

It will be of wood and iron, 1402 feet long by 360 feet wide, with a wing in the rear of the centre 208x210 feet, in which is a water tank 60 by 160 feet for the use of hydraulic machines.

Mr. Philip Quimby, of Wilmington, Del., has contracted to complete this building by October 1st next. He has broken ground, has much material worked out, and will put a large force at work as soon as the weather permits, and from the advanced state of his preparation, it is believed he will complete it by the time agreed on.

The horticultural hall is from the design of Mr. H. J. Schwarzmann, and will be built of iron and glass. It is under contract to Mr. John Rice, to be finished by September 15th, and the committee have full confidence in his completing it by that time.

The agricultural hall will be constructed entirely of wood and glass, and from the ease with which these materials can be obtained, no apprehension is felt in regard to having it ready in ample time.

The water and gas supply, grading and preparation of the grounds, means of transportation to and within the enclosure, railroad tracks in the main building and machinery hall, and all other matters, are receiving their full share of attention.

It will thus be seen that although the work to be done on the spot has been delayed by the severe winter, yet that portion which is to be done elsewhere has been pushed forward with great earnestness, and there need be no apprehension as to both buildings and grounds being ready for the reception of goods by the time fixed.

We shall endeavor to note the progress made from month to month and keep the readers of the JOURNAL informed on the mechanical and engineering matters connected with the great undertaking.

A great feature of the Exhibition will be not only the machines, but the full processes of manufacture, to a much greater extent than any former exhibition. K.

Firemen's Respirators.—Professor Tyndall has recently made considerable improvements in his respirator, which now promises to be of great value to firemen. The apparatus, when in use, is secured to the head of the wearer by two narrow elastic straps, one of which passes from the upper part of the apparatus round the head; the other passes from the lower part of the apparatus round the neck. The total weight when charged with the filtering materials is about nine ounces, and its advantages over previous forms are its lightness, simplicity of construction, and cheapness; the ease and rapidity of adjustment; no undue heating of the head, the face only being covered; no chance of derangement by the bursting of water tubes, etc., as none are used. The supply of air to the mouth and nose being perfectly free, there is therefore no excessive secretion of saliva.

On the alleged Expansion in Volume of various substances in passing by Refrigeration from the state of Liquid Fusion to that of Solidification.—The conclusions of Mr. Mallet upon the "Dilatation of Cast Iron and the Phenomena of the Crane Ladle," published in our February number, have excited so much interest that we republish here, from *Nature*, an abstract from his previous paper before the Royal Society, which has the above title. Mr. Mallet's well-known ability makes his opinion upon these matters of great scientific value.

Since the time of Reaumur it has been stated with very various degrees of evidence, that certain metals expand in volume at or near their points of consolidation from fusion. Bismuth, cast-iron, antimony, silver, copper, and gold are amongst the number, and to these have recently been added certain iron-furnace slags. Considerable physical interest attaches to this subject from the analogy of the alleged facts to the well-known one that water expands between 30° Fahr. and 32°, at which it becomes ice; and a more extended interest has been given to it quite recently by Messrs. Nasmyth and Carpenter having made the supposed facts, more especially those relative to cast-iron and to slags, the foundation of their peculiar theory of lunar volcanic action as developed in their work "The Moon as a Planet, as a World, and a Satellite" (4to, London, 1874). There is considerable ground for believing that bismuth does expand in volume at or near consolidation; but with respect to all the other substances supposed to do likewise, it is the object of this paper to show that the evidence is insufficient, and that with respect to cast-iron and to the basic silicates constituting iron slags, the allegation of their expansion in volume, and therefore their greater density when molten than when solid, is wholly erroneous. The determination of the specific gravity in the liquid state of a body having so high a fusing temperature as cast-iron is attended with many difficulties. By an indirect method, however, and operating upon a sufficiently large scale, the author has been enabled to make the determination with considerable accuracy. A conical vessel of wrought iron of about 2 feet in depth and 1·5 feet diameter of base, and with an open neck of 6 inches in diameter, being formed, was weighed accurately empty, and also when filled with water level to the brim; the weight of its contents in water, reduced to the specific gravity of distilled water at 60° Fahr. was thus obtained. The vessel, being dried, was now filled to the brim with molten grey cast-iron, additions of molten metal being made to maintain the vessel full until it had attained its maximum

temperature (yellow heat in daylight) and maximum capacity. The vessel and its contents of cast-iron when cold were weighed again, and thus the weight of the cast-iron obtained. The capacity of the vessel when at a maximum was calculated by applying to its dimensions at 60° the coefficient of linear dilatation, as given by Laplace and others, to its range of increased temperature; and the weight of distilled water held by the vessel thus expanded was calculated from the weight of its contents when the vessel and water were at 60° Fahr. after applying some small corrections.

We have now the elements necessary for determining the specific gravity of the cast-iron which filled the vessel when in the molten state, having the absolute weights of equal volumes of distilled water at 60° and of molten iron. The mean specific gravity of the cast-iron which filled the vessel was then determined by the usual methods. The final result is that, whereas the specific gravity of the cast-iron when cold is 7·170 it was only 6·650 when in the molten condition; cast-iron, therefore, is less dense in the molten than in the solid state. Nor does it expand in volume at the instant of consolidation, as was conclusively proved by another experiment. Two similar 10-inch spherical shells 1·5 inches in thickness, were heated to nearly the same high temperature in an oven, one being permitted to cool empty as a measure of any permanent dilatation which both might sustain by mere heating and cooling again, a fact well known to occur. The other shell, when at a bright red heat, was filled with molten cast-iron and permitted to cool, its dimensions being taken by accurate instruments at intervals of thirty minutes, until it had returned to the temperature of the atmosphere (53° Fahr.), when, after applying various corrections, rendered necessary by the somewhat complicated conditions of a spherical mass of cast-iron losing heat from its exterior, it was found that the dimensions of the shell whose interior surface was in perfect contact with that of the solid ball which filled it were, within the limit of experimental error, those of the empty shell when that also was cold (53° Fahr.), the proof being conclusive that no expansion in volume of the contents of the shell had taken place, which was further corroborated by the fact that the central portion was found much less dense than the exterior, whereas if the cast-iron expanded in consolidating the central portions must be more dense than the exterior.

It is a fact, notwithstanding what precedes and well known to iron founders, that certain pieces of cold cast-iron do float on molten cast-

iron of the same quality, though they cannot do so through their buoyancy, as various sorts of cast-iron vary in specific gravity at 60° Fahr., from nearly 7·700 down to 6·300, and vary also in dilatability; that thus some cast-irons may float or sink in molten cast-iron of different qualities from themselves through buoyancy or negative buoyancy alone; but where the cold cast-iron floats upon molten cast-iron of less specific gravity than itself, the author shows that some other force, the nature of which yet remains to be investigated, keeps it floating; this the author has provisionally called the repellent force, and has shown that its amount is, *cæteris paribus*, dependent upon the relation that subsists between the volume and "effective" surface of the floating piece. By "effective" surface is meant all such part of the immersed solid as is in a horizontal plane, or can be reduced to one. The repellent force has also relation to the difference in temperature between the solid and the molten metal on which it floats.

The author then extends his experiments to lead, a metal known to contract greatly in solidifying, and with respect to which there is no suggestion that it expands at the moment of consolidation. He finds that pieces of lead having a specific gravity of 11·361 and being at 70° Fahr. float or sink upon molten lead of the same quality, whose calculated specific gravity was 11·07, according to the relation that subsisted between the volume and the "effective" surface of the solid piece, thin pieces with large surface always floating, and *vice versa*. An explanation is offered of the true cause of the ascending and descending currents observed in very large "ladles" of liquid cast-iron, as stated by Messrs. Nasmyth and Carpenter. The facts are shown to be in accordance with those above mentioned, and when rightly interpreted, to be at variance with the views of these authors.

Lastly, the author proceeds to examine the statements made by these authors, as to the floating of lumps of solidified iron-furnace slag upon the same when in a molten state; he examines the condition of the alleged facts, and refers to his own experiments upon the total contraction of such slags, made at Barrow Ironworks, and a full account of which he has given in his paper on the true nature and origin of volcanic heat and energy, printed in Phil. Trans. 1873, as conclusively proving that such slags are not denser in the molten than in the solid state, and that the floating referred to is due to other causes. The author returns thanks to several persons for facilities liberally afforded him in making these experiments.

Editorial Correspondence.

NAVY YARD, WASHINGTON, D. C., Jan. 20, 1875.

Editor Journal Franklin Institute.

DEAR SIR: In your number for March, 1874, you published the record of a curious phenomenon displayed by a piece of iron under test, which exemplified the law of the "Increase of resisting power of metals" by stress. In the May or June number appeared a table with an analysis, embracing a number of similar experiments. The piece of iron whose action furnished the first article, appeared also in the second, viz., No. 1, and at the date of the strain reported, January, 1874, it had reached the limit of elasticity at 28250 lbs.

The specimen was laid aside for nearly one year, until Dec. 20th, 1874, when it was again pulled and broken at a strain of 29350 lbs.

The entire history of the specimen is as follows: It was hammered from old boiler iron, and turned down in the lathe to a cylindrical test piece ·800 of an inch in diameter and 1·5 inches long, was pulled in January, 1874, until the lever fell at the limit of elasticity, 24300 lbs.; weights were then taken off until it rebalanced at 23075 lbs. The piece was rested *seventeen hours* and repulled, when it reached 28250 lbs. before the lever fell, and was rebalanced at 26100 lbs. It was then laid aside for one year, and then broken at 29350 lbs.

Its measurements after the *second* pull were: diameter .677, showing a contraction of area equal to 28·3 per cent. of original diameter, and its length 2·07 inches, showing an increase of 38 per cent. of original length. After breaking, the diameter at the fracture was ·565 inch, showing entire contraction of area of 50·1 per cent., and length after fracture was 2·28, an increase of 52 per cent. in original length.

The point of beginning to stretch, on the final pull, was at 28400 lbs., almost identical with the point of limit of elasticity on the previous pull, one year before, and 96·7 per cent. of the final breaking strain. This point was not measured on the first and second pulls, but judging from the action of other similar pieces since broken, it was at about 70 per cent.

The iron was tough and fibrous, and in this test gave as tensile strength per square inch of original area 48140 lbs., and great ductility. The second day's limit of elasticity was 56190 lbs. per square inch, and the third and last breaking pull gave 58383 lbs., but with the ductility nearly all gone.

L. A. BEARDSLEE,

Commander, U. S. N.

Bibliographical Notices.

Catechism of the Locomotive. By M. N. Forney, Mechanical Engineer, New York, 1875. Published by *The Railroad Gazette*, 73 Broadway:—The author of this book of 650 pages has been long and favorably known as the Engineering Editor of *The Railroad Gazette*. His familiarity with railroad management in America renders him well qualified to instruct on all that pertains to the locomotive. The contents of this book have already appeared in the pages of the *Gazette*, its publication in that manner having extended over a period of more than a year. Its collection into one volume adds a book long wanted to the library of the engineer. Its production in catechetical form seems to have originated in a belief that "it has some very decided advantages in writing for those who have not acquired studious habits of thought," as "to such, the question asked presents first a distinct image of the subject to be considered, so that the explanation or instruction which follows is much more apt to be understood than it would be if no such questions had been asked." To prepare an acceptable work on such a subject as the locomotive in its American aspect requires on the part of the author a degree of familiarity with his subject attainable only in his capacity as a practical mechanical engineer. The subject has been treated in the volume before us with clearness and sufficient fullness for all practical purposes. It is written on what might be called a low plane, well fitted for the understanding of persons of moderate education. The absence of technical terms is very refreshing when we find the language so clear and not encumbered by many useless words. A translation of the German work "Katechismus der Einrichtung und des Betriebs der Locomotiv," by Georg Kisak, would have proved very useful if the translator should adapt its matter to the American form of locomotive. Mr. Forney has given the equivalent of this in the present volume, having used what seemed best for his purpose of the above-mentioned work, and added much that is original. Through all the pages we recognize the mode of thought of one who has been himself a student, not only of books, but of working machinery. To the steam engineer of modern days, the "Steam Indicator" is what the Stethoscope is to the physician. With it he diagnoses the breathing organs of his patient. Familiar as this instrument is to the marine engineer and the builder of stationary engines, its use on locomotives running maybe at forty to fifty miles an hour is not so easy an affair. The description in Mr. Forney's book of the process of using the indicator on locomotives is very clear, and the portion of the book devoted to this subject is in the

highest degree commendable. On page 50 is a very satisfactory illustration of steam expansion, presented in a mechanical manner, in which the card upon which the diagram is drawn is represented as a plane moving in front of the indicator pencil; yet in the illustration of the indicator shown in position on an engine on page 234, the Richards' indicator with the paper on the drum of this instrument is given as the proper method of using this instrument. This will work well at slow speeds, yet we are inclined to the belief that the flat card, as shown on page 47, would prove more serviceable at high speeds. We have seen cards taken in this way from engines making 900 revolutions per minute.

We would call attention to the novel and ingenious illustration of unequal strains on iron plates, as shown by a hole punched in a rubber band, p. 93. This round hole in the band represents a rivet hole; if now across the band two parallel lines be drawn as if directly across the centre of the hole, when the band is stretched these lines will not remain parallel but will separate widest next to the hole, indicating where the fibers of the rubber are stretched the most. The author in this manner shows what may be the case when plates of iron are similarly stretched, a fracture being liable to start next the hole, "after which the plate will be broken, as it were, in detail." An interesting description of the strains in the bent tube of the Bourdon steam gauge has attracted our attention. The portion of the book devoted to the subject of springs as used on locomotives, and the theory of equalization of load in the springs, seems from a foot note to have been, mainly, taken from "Die Schule des Locomotivführers," by Messrs. J. Brosuosc and R. Koch, while the frame work and its arrangement is entirely new, and very clear.

In Part XVI., which treats of screw threads, bolts and nuts, he advocates the standard as adopted by the Franklin Institute, fully illustrating its general principles, and at the same time pointing out the need of intelligent forethought on the part of the workmen who have the care of these tools. He says that in many shops the men who make the taps have only a vague idea that so long as they get the proper number of threads to the inch they are doing all that is necessary to secure uniformity. He urges care on their part to secure the great advantage that should result from uniformity of standard screws and threads. It is impossible for us to allude in detail to all the subjects treated in this book, but we commend it not only to practical mechanics but to the general reader. We cannot help regretting that the mechanical execution of the book is not of a higher order. It is illustrated by 250 engravings and twenty full-page plates of various styles of locomotives. Many of the cuts are white lines on a black ground. These heavy masses of black are always difficult to print, but the greater part of those in this volume bear unmistakable indications of inexcusable carelessness on the part of the printer.

The black cuts look as if a very old dry inking roller had been used. The type is good, and all the pages have been well "made ready," showing care in this direction. The paper is good, and extra calendered, and has been printed dry, but the ink has bad drying properties and "sets off" on the opposite pages, as well as smudges when touched with the finger. The matter is indeed worthy of much finer work in printing. Any one familiar with the illustrated books published in France, must have noticed the perfection of the color shown in the masses of black in the cuts of the character used in this book. Some experiments which we have seen conducted in the printing houses of this city seem to indicate that when broad masses of black with light lines are required, they should be printed on damp paper, with good new inking rollers and a fine quality of ink. Familiar as we have been with the subject matter of the Catechism as it appeared week after week in the *Gazette*, yet the collection as now presented reads almost as a new composition, and is indeed a valuable contribution to the literature of the workshop. S.

Franklin Institute.

HALL OF THE INSTITUTE, Feb. 17th, 1875.

The stated monthly meeting was called to order at 8 o'clock P.M., the President, R. E. Rogers, in the chair.

The minutes of the stated meeting of January were read and approved.

The Actuary submitted the minutes of the Board of Managers and of the several Standing Committees, and reported the following from the proceedings of the Board at their meeting held February 10th, 1875.

To the Board of Managers of the Franklin Institute:

GENTLEMEN: At a meeting of the Committee on Sciences and the Arts, held January 18th, 1875, it was

Resolved, That the award of the Elliott Cresson Gold Medal to Joseph Zentmayer, for many and great improvements in the construction of microscopes, object glasses and accessories, be recommended to the Board of Managers of the Institute.

Respectfully, JNO. C. CRESSON, *Chairman.*

On motion, it was

Resolved, That the Elliott Cresson Gold Medal be awarded to Joseph Zentmayer, in accordance with the recommendation of the Committee on Science and the Arts.

The Actuary also reported the following donations to the Library, received from Jan. 23d to Feb. 10th, 1875:

Annales des Ponts et Chaussées, for October and November, 1874. From the Editor.

Monthly Notices of the Royal Astronomical Society, Vol. 35, No. 2, December, 1874. From the Society.

Informe al Supremo Gubierno del Peru sobre una Expedicion al Interior de la Republica, por John W. Nystrom. From the Author.

Verhandlungen des Naturhistorisch-Medicinischen Vereins zu Heidelberg, 1874. From the Society.

Jahrbuch der K. K. Geologischen Reichsanstalt, for July, August, September, 1874, Vol. 24. From the Society.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale, for December, 1874. Paris. From the Society.

Chief Engineer's Monthly Report of the Manchester Steam-Users' Association for the Prevention of Steam Boiler Explosions, for November, 1874. Manchester. From the Association.

Mr. Bullock, from the Library Committee, reported that the Board of Managers has made an appropriation of $5000 for the purchase of books for the Library. A considerable number of books have already been purchased, and others ordered, and the entire amount will be expended as rapidly as the proper selections can be made.

At the request of the Secretary, Mr. Zentmayer then gave an interesting account of the progress of the improvements in microscopic lenses, and of the difficulties to be overcome in those for the solar or gas microscope, to obtain a perfectly flat field on the screen, and illustrated his late improvements by using alternately lenses of his own make and those of the best French makers, to throw images on the screen with the oxy-hydrogen light.

The Secretary then described, with the aid of the lantern, an improved life raft and rails for ships, the invention of Mr. R. W. Newbury, New York. This invention consists of two hollow cylinders of sheet metal, about 8 inches in diameter and 10 or 12 feet long, having conical ends, held in a position parallel to each other,

and three or four feet apart, by four bars of metal or wood. Across the whole is stretched woven wire or netting.

The raft is supported on edge at the side of the ship's deck by iron stanchions, and fastened in such a manner that it is easily detached when required, thus forming a necessary portion of the ship under ordinary circumstances, and a means of saving life in case of disaster.

Also an improved knife for druggists' use in cutting dried herbs, and also for cutting tobacco, the invention of Jno. G. Baker, the peculiarity of which consists in so connecting the blade to the lever, that in descending the blade is held parallel with the base of the instrument, and at the same time has a horizontal motion, thus giving it a sliding motion through the substances to be cut.

Under the head of new business Mr. C. Chabot offered the following:

"*Resolved*, That a committee be appointed to review, and, if necessary, revise, the By-Laws and Rules, and report to the Institute as early as practicable; the committee to consist of nine members, not more than four being chosen from the Board of Managers. The President will be aided in his choice by nominations."

Mr. Close remarked that he could see no reason for dictating regarding the number of Managers to be placed on such a Committee; that the Managers did not claim to know more of such matters than other members of the Institute, nor should they be debarred the privileges nor exempt from the duties of other members by reason of their being on the Board. He moved that the portions of the resolution relating to the Managers be struck out, which was accepted by the mover.

Mr. Wm. P. Tatham asked the mover to state some reason why such a committee should be raised, stating that he knew of no reasons for or against.

Mr. Chabot replied that it was generally believed that some changes in the By-Laws were desirable, and as the last edition printed is exhausted it would be better to make such amendments as are wanted before printing a new edition.

Mr. Close remarked that the mode of amending the By-Laws was clearly laid down, and if any changes were desirable let them be stated and presented to just such a meeting as this.

Mr. Sellers said that the effect of passing this resolution would be to open a long and unpleasant discussion, and he hoped he might

not be placed on such a committee, as he was heartily tired of tinkering with By-Laws.

On putting the Resolution it was lost.

Mr. Tatham called attention to the fact that the election of one of the Vice-Presidents, Dr. Rogers, to the Presidency left a vacancy in that office, and moved that the Institute go into an election for a Vice-President to fill this vacancy, which was adopted.

Mr. Bloomfield H. Moore was the only one placed in nomination.

The Chair appointed Mr. Chas. Bullock and Chas. S. Close as tellers.

All the votes cast were for Mr. B. H. Moore, who was declared elected.

The President then announced the standing committees of the Institute for the current year as follows:

On Library.—Chas. Bullock, Saml. Sartain, Wm. P. Tatham, Jos. M. Wilson, Geo. F. Barker, Coleman Sellers, J. B. Knight, B. H. Moore, J. W. Nystrom, Isaac Norris, Jr.

On Minerals.—F. A. Smith, Theo. D. Rand, Saml. B. Howell, Clarence Bement, Wm. H. Wahl, E. J. Houston, John C. Trautwine, Robt. Grimshaw, Edward F. Moody, Jos. M. Wilson.

On Meteorology.—Pliny E. Chase, Hector Orr, Isaac Norris, Jr., John Wise, J. E. Mitchell, Thos. S. Speakman, Jas. A. Kirkpatrick, David Brooks, A. Purves, Wm. H. Wahl.

On Models.—Wm. B. Bement, Edward Brown, Theo. Bergner, John Goehring, L. L. Cheney, Edwin Smith, C. Chabot, J. B. Knight, S. Lloyd Wiegand, D. S. Holman.

On Arts and Manufactures.—A. B. Barry, Geo. V. Cresson, Hector Orr, Coleman Sellers, Jr., W. B. LeVan, S. M. Ward, M.D., H. W. Bartol, J. Sellers Bancroft, Alfred Mellor, Cyrus Chambers, Jr.

On Meetings.—J. B. Knight, B. H. Moore, Saml. Sartain, Washington Jones, Geo. F. Barker, Henry Cartwright, Chas. S. Close, Wm. P. Tatham, J. Sellers Bancroft.

The President announced that hereafter the rule requiring the janitor to take the names of members on entering the meetings, would be enforced.

The Secretary stated that as yet but few of the copies of the exercises to commemorate the 50th anniversary of the foundation of the Institute, held in February, 1874, had been taken, and recommended members to buy them.

Mr. Weaver asked what is to become of the amendments to the by-laws proposed by Mr. LeVan at the last stated meeting.

The President stated that they not having been advertised as required by Article 16, they could not be acted on to-night.

Mr. Eldridge did not agree with the chair, because were that the case it would be possible for the officer whose duty it is to advertise them, to defeat action during the entire term of his office, on any amendment to which he was opposed, simply by neglecting or refusing to advertise it.

The Secretary stated that he had been requested by the mover of the amendments not to advertise them, as he (Mr. LeVan) had determined to withdraw them at this meeting, and that he was quite certain the seconder would consent to the withdrawal; that he (the Secretary) had taken counsel with several members, and becoming satisfied that he was justified in the omission, did not advertise them.

The chair decided that the rule requiring the advertisement of the proposed amendments not having been complied with, they will be considered to-night and acted on at the next stated meeting.

In reply to a question whether or not he intended to withdraw the proposed amendments, Mr. LeVan stated that he had intended doing so, but the seconder objected, and now he intended pressing them.

In reply to a question of Mr. Tatham, he further stated that his reason for urging the first amendment was that many members are engaged at their usual occupation until 6 P. M., and cannot get to the Institute before 8 o'clock, and his reason for desiring the second amendment was that he thought it would be better to have more fresh members in the Board of Managers, and he therefore renewed his proposed amendments.

Mr. Close moved that the matter be postponed until after some copies of the by-laws are printed, so that members can act more intelligently.

Mr. Tatham said that if they can be postponed at all, they can be postponed indefinitely, and moved that they be indefinitely postponed.

The chair decided that as the by-laws required that proposed amendments be acted on at the next stated meeting after they are offered, a motion to postpone beyond that time is not in order.

On motion, the meeting then adjourned.

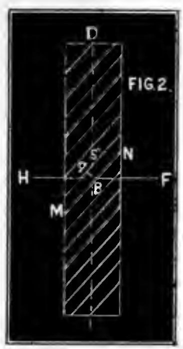
J. B. Knight, *Secretary.*

Civil and Mechanical Engineering.

ON SPIRAL WHEELS.*

By Professor L. G. FRANCK, of the University of Pennsylvania.

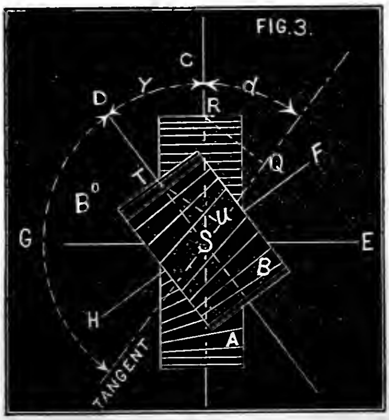
The recent exhibition of the Franklin Institute in Philadelphia presented, among other interesting contrivances for transmission of motion, a number of spiral wheels of various constructions. The peculiarities of the properties of some of these wheels induced me to attempt to comprehend all varieties under one head; in other words, to derive some formulæ that express their axial position, as well as the tangential direction of two spirals in contact, and also the velocity of the sliding motion of teeth.



(1). Let A and B be two thin rectangular plates of flexible material—which I shall call for brevity's sake, planes—upon which right parallel lines are drawn equally distant from each other (Figs. 1, 2), B q = A t, whose angles at L A C and N B D may be equal or unequal to each other. Let the angle N B D = β and L A C = α. If these

* Reauleaux' work was consulted in the preparation of this article.

planes are regarded as the developments of circular cylinders, we may, after we have placed B upon A so that M N and K L coincide, curve them back to their original cylindrical shape, leaving the element at A and B in contact. The right lines on the planes will then become screw lines or spirals, as they are sometimes termed. The planes G E and H F will form a certain angle, depending on the obliquity of the lines K L and M N (Figs. 1 and 2), to be denoted by γ, and which is for geometrical reasons equal to the angle D S C (Fig. 3), formed by two planes perpendicular to the plane of the



paper. The line of contact will form the tangent to the spiral at A and B respectively. The angles that the lines S C and S D make with the tangent retain their relative value, as regards the horizontal projection, and are therefore equal to α and β respectively (Fig. 3). Considering these cylinders as the pitch cylinders and the lines upon them as pitch lines, we are enabled to derive equations of condition that belong to spiral wheels of all varieties. From Fig. 3 it is evident that

$$\beta + \gamma + \alpha = 180^\circ \tag{1}$$

Further, as we have assumed the distances between the parallel lines on both planes to be equal (Fig. 1 and 2), we have

$$A\,t = A\,s.\ \sin \alpha, \text{ and } B\,q = B\,s.\ \sin \beta.$$

Hence, A s. $\sin \alpha =$ B s. $\sin \beta$; but as A s and B s will form the pitch on the cylinders (Fig. 3), we find, introducing the known formula for the pitch, the subsequent expression:

$$\frac{2\pi a}{N_a} \sin \alpha = \frac{2\pi b}{N_b} \sin \beta;$$

where a and b denote the radii of the wheels A and B, and N_a and N_b their respective number of teeth.

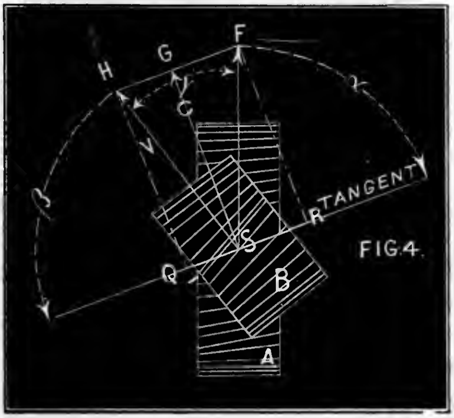
From the above equation we get the ratio:

$$\frac{N_a}{N_b} = \frac{a \sin \alpha}{b \sin \beta} \qquad (2)$$

but as a sin α = R Q, and b sin β = T U ; we find also (Fig. 3),

$$\frac{N_a}{N_b} = \frac{R\,Q}{T\,U}. \qquad (3)$$

It appears from these expressions that the numbers of teeth of two spiral wheels in contact are not in direct proportion to the radii; but are as the perpendiculars to the tangent, that is as R Q is to T U. If, further, the velocities of a point on the cylinders A and B are V_a and V_b, we obtain the velocity of sliding motion of a point along two teeth, when we resolve these velocities into components in the direction of the tangent and perpendicular to it.



Let S F and S H (Fig. 4), be equal to V_a and V^b, the respective velocities; S R, S G and S Q and Q H the components. The velocity of sliding motion is then U = S R + S Q ; hence

$$U = C \text{ cotg } \alpha + C \text{ cotg } \beta = C\,(\text{cotg } \alpha + \text{cotg } \beta). \qquad (4)$$

In accordance with the doctrine of maximum and minimum, U becomes a minimum when α is put equal to β.

It appears, then, in order to get a minimum velocity of sliding motion, we must put $\alpha = \beta$. As velocity is one of the factors in the

formula of mechanical effect of friction that increases friction, it is obvious that to diminish friction we must decrease the velocity of sliding friction.

(2). The following examples will explain the use of the derived formulæ :

Example 1. Required the respective radii, a and b, of two spiral wheels; also the pitch of each, and the sliding velocity at the flanks of two teeth in contact.

Given, the number of teeth $N_a = 40$, and $N_b = 20$; the normal axial distance $a + b = 10$ inches; the axial angle $\gamma = 40°$, and one of the tangential angles, $\beta = 60°$.

To find the other tangential angle, we have (formula 1)

$$\alpha = 180 - (40 + 60) = 80°.$$

To find the radii, b and a, we have, $a + b = 10$, and, from formula 2, we have,

$$\frac{b}{a} = \frac{N_b \sin \alpha}{N_a \sin \beta} = \frac{1}{2} \cdot \frac{\sin 80°}{\sin 60°} = 0{\cdot}5686.$$

Hence, $a = \dfrac{10}{1{\cdot}5686} = 6{\cdot}375$ in., and $b = 10 - 6{\cdot}375 = 3{\cdot}625$ in.

To find the pitch, p_a, of wheel A.

This, for the normal division, is

$$N = p_b \sin \beta = \frac{2 \pi b \sin \beta}{N_b} = \frac{2 \pi\, 3{\cdot}625 \times 0{\cdot}866.}{20}$$

$$p_b = \frac{2 \pi\, 3{\cdot}625}{20} = 1{\cdot}138 \text{ inches, and } p_a = \frac{2 \pi\, 6{\cdot}375}{40} = 1{\cdot}001 \text{ inches.}$$

To find the velocity of sliding motion :

$$U = C(\text{cotg } 60° + \text{cotg } 80°) = 0{\cdot}7537\ C.$$

Example 2. If the given values of Example 1 remain, with the exception that we make $\alpha = \beta$, in order to get a minimum sliding motion, what will be the above required quantities?

To find the tangential angles: $2\,\alpha = 180 - 40$. Hence, $\alpha = \beta = 70°$.

To find the radii, a and b :

$$\frac{b}{a} = \frac{N_b}{N_a} = \frac{20}{40} = \frac{1}{2}, \text{ and } a + b = 10.$$

$$\text{Hence, } b = \frac{10}{3} \text{ inches; } \quad a = \frac{20}{3} \text{ inches.}$$

The pitch will be $p_a = p_b = 1{\cdot}047$ inches, and the sliding velocity, $U = 2 \cot 70\ C = 0{\cdot}728\ C$.

From this we see that the wheels of Example 2 will mechanically be more perfect than the first set on account of the less sliding velocity. The calculation is also less complex, as $a = 2b$, and the pitch is the same for each.

Example 3. Let all quantities remain that are given in Example 1, except make the tangential angle $\alpha = 90°$. Required the radii, pitch, and sliding velocity.

To find the tangential angle, $\beta = 180 - (90 + 40) = 50°$.

To find the radii, we have

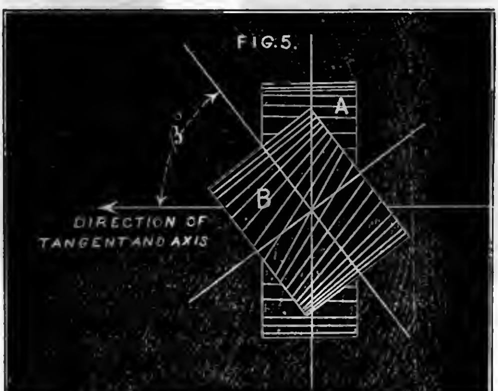
$$\frac{b}{a} = \frac{1}{2} \cdot \frac{\sin 90}{\sin 50} = 0{\cdot}6525, \text{ and } b + a = 10.$$

Hence, $a = 6{\cdot}051$, and $b = 3{\cdot}949$ inches.

To find the pitch of both wheels :

Pitch of $A = p_a = \dfrac{\text{normal division}}{\sin 90°}$. It follows, then, that $p_a =$ normal division, which indicates that wheel A becomes an ordinary spur wheel, (Fig. 5.)

FIG. 5.



$$p_a = \frac{2\pi a}{N_a} = 0{\cdot}95\,;\ p_b = \frac{2\pi b}{N_b \sin 50} = \frac{1{\cdot}239}{\sin 50°} = 1{\cdot}617 \text{ inches.}$$

To find the velocity of sliding motion :

$U = C(\cot 50 + \cot 90) = 0{\cdot}8391\ C$, a quantity which is greater

than the one found in Example 2, indicating a less perfect mechanical contrivance compared with that in Example 2. This contrivance, however, has the advantage that one of the wheels becomes a spur wheel.

Example 4. Given $N_a = N_b$; $\alpha = \beta$, and the axial angle $\gamma = 90°$. Required the radii, pitch, and sliding velocity.

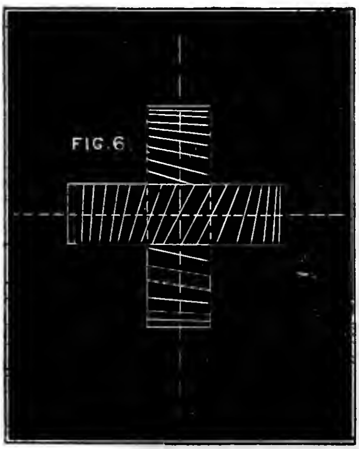
To find the tangential angles, $2\alpha = 180 - 90$. Hence, $\alpha = \beta = 45°$.

To find the radii: $\frac{a}{b} = \frac{\sin 45}{\sin 45}$. From this it follows $p_a = p_b$.

$a + b = 10$. Hence, $a = 5$, and $b = 5$ inches.

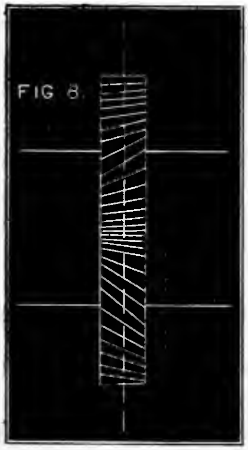
To find the sliding motion: $U = C(\text{cotg } 45 + \text{cotg } 45) = 2\ C$.

It appears then that, under the above assumptions, both wheels become equal to each other in size, and that both become either right or left handed spirals, (Fig. 6.)



Another remarkable case is, that if B is made a driver working the two followers, A and C, arranged as Fig. 7 exhibits, both followers will move in contrary directions, indicated by the arrows, Fig. 7. That is similar to a set of bevel wheels, and different from that of spur wheels, provided the above three wheels have all right or left handed spiral teeth.

Example 5. If we make the axial angle $\gamma = 0$, then both axes of the wheels become parallel. Given $\alpha = \beta$, $N_a = N_b = 40$, and $a + b = 10$. Required the radii, pitch, and sliding motion.



It is in general, $\alpha + \beta = 180$. Hence $\alpha = 180 - \beta$.

This points out, as the sum of both angles is equal to 180°, that both wheels become spur wheels with spiral threads, of which one must have a left handed spiral, while the other must have a right handed one, (Fig. 8.)

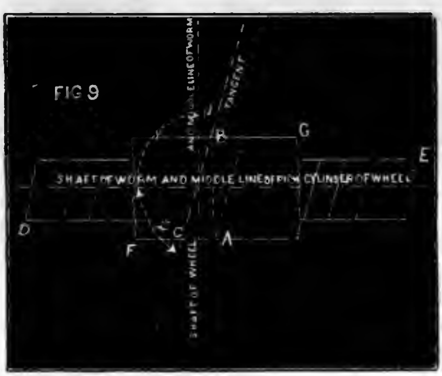
From the above assumption we further get $\alpha = \beta = 90°$, which makes both wheels of equal size; a = b = 5 inches.

$$p_a = p_b = \frac{2\pi 5}{40} = 0{\cdot}7852 = \text{pitch}.$$

$$U = (\text{cotg } 90° + \text{cotg } 90°)C = 0.$$

From the fact that in formula (1) any two of the three angles may be assumed, it is obvious that a great variety of wheels that work together can be constructed. The last assumption gives two spur wheels with straight teeth, and, therefore, the lateral sliding motion equals zero.

(3). Another contrivance that deserves to be taken notice of, is the wheel and worm or endless screw. The worm consists of a cylinder, and thread continuously wound around it. The tangent drawn to the thread gives the obliquity of the teeth of the wheel.



Let F G (Fig. 9) be the developed pitch cylind r of the worm, and D E that of the wheel. If we denote by $p_a = A\,C$, the pitch of the

worm, which is here a portion of an element of the cylinder, and therefore a straight line, we find for the angle of inclination :

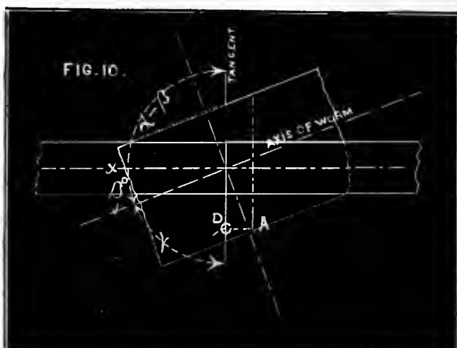
$$\text{Tang } A\,B\,C = \frac{A\,C}{A\,B} = \frac{p_b}{2\,\pi\,b} = \text{tang } \beta.$$

Hence the pitch of screw and wheel :

$$p_b = 2\,\pi\,b \text{ tang } \beta = p_a = \frac{2\,\pi\,a}{N_a}$$

provided the axial angle $\gamma = 90°$.

We have also $\frac{N_a}{N_b} = \frac{n_b}{n_a}$, where n_b and n_a are the revolutions of the worm and wheel respectively. Commonly but one tooth is taken for the worm ; therefore $N_b = 1$, which gives $N_a = \frac{n_b}{n_a}$ Further $\alpha + \beta + 90 = 180$, and $a + b = m$, which expressions enable us to get other required quantities. An ordinary spur wheel may be driven by a worm, a statement that has already been made in connection with Fig. 5, if the axis of the worm is turned just about the angle β (Fig. 10) from its former position (Fig. 9). It is, however, required to



make now the pitch of the wheel, as A C stands oblique to the face of the wheel, $\frac{p_a}{\cos \beta}$, where p_a denotes the former pitch of the wheel.

(4). The friction between worm and wheel is considerable. It is therefore of importance to know what ratio with regard to the radius of the worm and to its pitch should be employed in order to diminish friction.

Applying the well known formula derived in mechanics,

$$\frac{P_1}{P} = \frac{1+f.\frac{2\pi b}{p_b}}{1-f.\frac{p_b}{2\pi b}},$$ where P denotes the force

tangent at the circumference of the pitch circle of the worm to overcome the resistance and friction, while P is the force required to overcome the resistance only; we find, introducing for the coefficient of friction, $f = 0{\cdot}16$, the subsequent formula of approximation:

$$\frac{P_1}{P} = 1 + \frac{b}{p_b},$$ where b denotes the radius of

the worm, and p_b the pitch. It is evident, in order to gain useful effect, that we must give $\frac{b}{p_b}$ its least value. Morin recommends $b = 3p_b$; Redtenbacher, $b = 1{\cdot}6p_b$, and Reauleaux gives as a rule $b = p_b$, which, as we will see, give a great difference in the final result. If we substitute the above values, we find:

$$P_1 = 4P; \; P_1 = 2{\cdot}6P, \text{ and } P_1 = 2P.$$

Reauleaux' rule gives, under ordinary circumstances, a very small cylinder. If, however, we apply his formula, we shall still have a loss of 50 per cent. of useful effect.

(5). Some other varieties are well worth remarking. If we make in the fundamental formula $a+b = m$; $a = b = \infty$, we obtain two racks, one of which may be made the driver and the other the follower. Let A and B (Fig. 10) be two racks of which the parallel lines

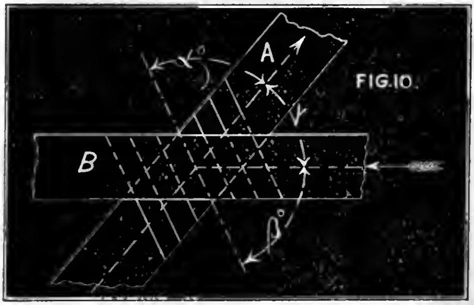


FIG. 10.

of both have equal normal distances. We have the algebraic sum of

α, γ and $\beta = 180°$, and the velocity for sliding motion: $U = (\text{cotg } \alpha + \text{cotg } \beta)C$.

Example. Given the axial angle $\gamma = 90$, and $\alpha = \beta$; further, $a = b = \infty$. To find the velocity of each rack (Fig. 11).

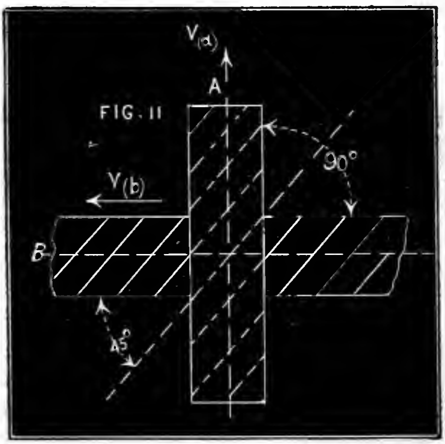
It is $\gamma + \beta + \alpha = 180°$. Therefore, $90 + 2\alpha = 180$. Hence $\alpha = \beta = 45°$.

From Fig. 4 we have, $C = V_a \sin \alpha$, and

$$C = V_b \sin \beta.$$

Whence $$\frac{V_a}{V_b} = \frac{\sin \beta}{\sin \alpha} = \frac{\sin 45°}{\sin 45°} = 1.$$

Hence, $V_a = V_b$.



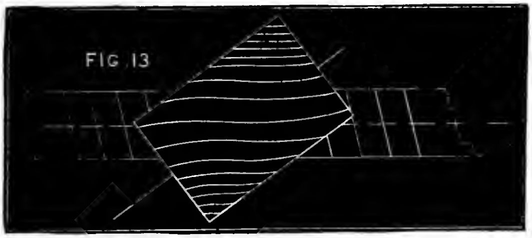
The relative velocity of sliding motion is

$$U = C(\text{cotg } \alpha + \text{cotg } \beta) = C(\text{cotg } 45° + \text{cotg } 45°) = 2\,C.$$

(6). If a rack is worked (Fig. 12) by a screw-wheel we have, when the tangential angle of the teeth of the rack is α, and the axial angle equal to γ, the tangential angle of the wheel $\beta = 180 - (\alpha + \gamma)$, while the velocity of sliding motion along the tooth is again $= C(\text{cotg } \alpha + \text{cotg } \beta)$. It is easily to be seen that in the preceding cases a considerable lateral pressure is produced.

If the obliquity of the teeth of the rack, upon

which the value of the lateral pressure depends, is arranged so that



it is just balanced by the sliding friction that acts in the opposite direction, the rack (Fig. 13) moves in its ascribed path, mathematically speaking, without guides. This principle was ingeniously applied, first to my knowledge, by Messrs. W. Sellers & Co.

AN ACCOUNT OF SOME EXPERIMENTS MADE AT MULHOUSE, BY MONS. BURNAT, ON THE EFFICIENCY OF SEVERAL KINDS OF COATING IN PREVENTING THE LOSS OF HEAT BY RADIATION FROM THE SURFACES OF STEAM-PIPES.

By Chief Engineer B. F. ISHERWOOD, U. S. Navy.

During the session of "La Société Industrielle de Mulhouse," Elsass, on the 26th of January, 1859, there was read the report made by Mons. E. Burnat for the Commission charged, among other matters, with the examination of the plastic composition or mortar proposed as a coating by Mons. Pimont for the prevention of heat-radiation from the surfaces of steam-pipes, hot water-pipes, etc. As very few experiments appear to have been made on this subject, though one of the highest industrial importance, and as these of Mons. Burnat have never been published in English, I have selected all the observed data given in the above named report, converted it from French into British measures, and, arranging it in my own way, have made the calculations and drawn the conclusions necessary to render the results of use to the practical engineer. I wish distinctly to here state that I have taken nothing from the report except the observed data; indeed, it contains nothing else to take.

The experimental apparatus was as follows: five groups, each consisting of four cast iron pipes of 4·7245 inches external diameter, and

exposing an aggregate surface of 58·4717 square feet per group, were arranged parallel to each other with intervening spaces of 39$\frac{3}{8}$ inches. The thickness of the metal of the pipe was 0·25 inch. The groups were inclined 0·05 in 1·00, and the highest point of each was connected with a steam-pipe supplied from the same boiler, while the lowest point was connected with a tank properly constructed and arranged for the reception of the water resulting from the condensation of the steam. Four of the groups were covered with the different non-conducting substances proposed, and the fifth was left uncovered or bare to furnish the base of comparison. The apparatus was placed in a large unheated hall, free from air currents; and the condensation of the steam within the pipes was wholly due to the difference between the temperature of that steam and the temperature of the air surrounding them. By this system, the trials of the efficiency of the different non-conducting substances were made simultaneously and under identical conditions, the same steam-pressure existing within the pipes of each group, and the same air-temperature surrounding them. For facility of reference, the groups have been numbered from 1 to 5, in the following Tables, Nos. 1 and 2 containing the data and results of the experiments.

The non-conducting substances with which the pipes of each group were surrounded were as follows (Table No. 2):

1*st Group.* The pipes of this group were first covered with common straw to the thickness of six-tenths of an inch, laid lengthwise; and around this wisps or tresses of the same straw were wound spirally and close together.

2*d. Group.* The pipes of this group were left bare, and exposed to the air their cast iron surfaces in the state in which they left the mould.

3*d Group.* The pipes of this group were enclosed in hollow tiles or pipes of pottery, whose inner diameter was greater than the outer diameter of the steam-pipes, whereby an annular air-space was left between the pottery and iron surfaces. The pottery-pipes were held in place by iron wire, and coated with a mixture of loamy earth and chopped straw, which, in its turn, was covered with tresses of common straw.

4*th Group.* The pipes of this group were covered with cotton waste to the thickness of one inch, held in position by wrapping cloth fastened with strings.

5th Group. The pipes of this group were coated with a plaster composition furnished by Mons. Pimont, consisting essentially of clay kneaded in water and mixed with cows' hair, and perhaps other substances. Its application to the surface of a pipe was begun, by the help of netting, with a coating of variable thickness, along which laths were placed nearly touching, and held in position by twine. On these another coating of the plaster was spread, and then laths again, and so on, until an aggregate thickness of 2·3622 inches was built up. The total number of experiments made with this substance was twelve, in nine of which (5th group) the plaster was left with its natural dark brown or mud color, and in three of which (5th group *bis*) its surface was painted white, with a view to ascertain whether its non-conducting efficiency was affected by color.

Finally, with the pipes of the second group, two trials (2d group *bis*) were made of the non-conducting efficiency of some old felt which had been treated with caoutchouc and used on machines for printing textile fabrics. The thickness of this coating is not given.

Before proceeding to experiment with the non-conducting substances above described, eleven trials were made with the apparatus in its bare state, none of the pipes being covered, to ascertain whether each group under identical conditions of steam-temperature and air-temperature, would condense the same weight of steam in the same time. The results will be found in Table No. 1, under the numbers of the different groups, expressed relatively. The greatest discrepancy for any one experiment is 5·9 per centum; but the mean of the eleven experiments gives, for the different groups, 2·3 per centum as the maximum discrepancy. Calling the weight of steam condensed in a given time by the pipes of the 5th group, 100·0; then, the weight of steam condensed in the same time by the pipes of the 4th group, will be expressed by 101·4; by the pipes of the 3d group, 101·0; by the pipes of the 2d group, 102·3; and by those of the 1st group, 101·0. The mean results have, therefore, a possible error of 2·3 per centum.

The experiments were made with absolute steam-pressures varying from $1\frac{1}{8}$ atmospheres, or 16·523 pounds per square inch above zero, to two atmospheres or 29·375 pounds per square inch above zero. The pressures were from observation, and I have placed opposite to them in each case the corresponding temperature according to Regnault. The air-temperatures were from observation, and varied between 27 and 47 degrees Fahrenheit.

The objections to the experiments are their fewness, their shortness, and the narrow limits of temperature within which they were made. The substances tried were also too few, and, in some cases, their thickness was not ascertained. The results, exceedingly valuable notwithstanding, will be found, together with the data, in the Tables herewith given, numbered respectively 1, 2, and 3.

The condensation of the steam in the steam-pipes is due wholly to the difference between the temperature of that steam and the temperature of the air surrounding the pipes; and though the discrepancies are numerous and the range of temperature restricted, yet the general result of all the experiments shows the condensation to be in the direct ratio of the difference of the above mentioned temperatures; that is to say, with a difference of one hundred degrees the condensation is twice as great as with a difference of fifty degrees. We can, therefore, depend upon the mean condensation as belonging to the mean difference of temperature, and establish constants from them for the several cases.

Taking first, the bare or uncovered steam-pipes, we find that for them the mean of the results in Table No. 1, and in the column headed "2d Group" in Table No. 2, having regard to the quantity of surface in use in both Tables, is a difference of temperature of 193·21 degrees Fahrenheit, and a corresponding condensation per hour per square foot of surface of 0·584413009 pound weight of steam of the absolute pressure of 22·031 pounds per square inch. Hence for one degree Fahrenheit difference of temperature, cast iron in the natural state and 0·25 inch thick, will condense by exposure in still air 0·00302422672 pound weight of steam of the absolute pressure of 22·031 pounds per square inch per hour per square foot of heat radiating surface. This is equivalent to a heat radiation per hour of 2·874757336690 Fahrenheit units from a square foot of cast iron in its natural state and 0·25 inch thick, for a difference of temperature of one degree Fahrenheit on the opposite sides. These are very valuable constants, and will be found of great use for many purposes in engineering.

The Fahrenheit unit of heat referred to, is the quantity of heat required to raise the temperature of one pound of water at the freezing point and under the atmospheric pressure, one degree Fahrenheit.

TABLE No. 1.—Containing the Data and Results of The Experiments made to Ascertain the Quantity of Heat Radiated from Bare Cast Iron Steam Pipes, under the Experimental Conditions. Outside Diameter of Pipes 4·7245 Inches, Thickness of Metal 0·25 Inch, Radiating Surface of each Group of Pipes 58·4717 Sq. Ft.

Duration of the Experiments in minutes.	Steam-Pressure in the Pipes in pounds per square inch above zero.	Temperatures, in Degrees Fahrenheit.			Weight of Steam Condensed per Hour, per Square Foot of the Heat-Radiating Surface of the Steam Pipes; Expressed Proportionally for the Different Groups of Pipes.					Pounds weight of Steam condensed per hour per square foot of the Heat-Radiating Surface of the Steam-Pipes.
		Of the steam in the pipes.	Of the air surrounding the steam-pipes.	Difference of the two preceding columns.	First Group.	Second Group.	Third Group.	Fourth Group.	Fifth Group.	
52	16·523	217·96	46·85	171·11	102·0	106·0	101·0	102·0	100·0	0·499759
56	16·523	217·96	39·20	178·76	98·8	99·9	99·2	100·8	100·0	0·501807
51	18·359	223·42	44·60	178·82	98·3	100·2	98·3	100·8	100·0	0·534578
56	18·359	223·42	39·65	183·77	102·4	102·8	101·4	102·1	100·0	0·585783
54	18·359	223·42	33·80	189·62	102·6	103·4	101·9	100·0	100·0	0·561205
40	22·081	233·17	40·10	193·07	100·5	101·1	99·0	101·4	100·0	0·602169
58	22·031	233·17	39·65	193·52	102·9	102·8	102·3	101·3	100·0	0·600121
55	25·703	241·60	42·35	199·25	103·2	105·9	104·5	104·5	100·0	0·649277
52	25·703	241·60	41·00	200·60	100·7	102·4	101·3	101·0	100·0	0·634940
53	29·375	249·05	46·85	202·20	102·3	102·6	101·9	100·6	100·0	0·657470
56	29·375	249·05	39·65	209·40	97·0	98·0	100·6	100·6	100·0	0·682892
Means	22·031	233·17	41·24	190·93	101·0	102·3	101·0	101·4	100·0	0·587273

TABLE No. 2, CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE TO ASCERTAIN THE QUANTITY OF HEAT RADIATED FROM CAST IRON STEAM PIPES, UNDER THE EXPERIMENTAL CONDITIONS: WHEN BARE AND WHEN COVERED WITH THE DIFFERENT COATINGS DESCRIBED BELOW. OUTSIDE DIAMETER OF PIPES, 4·7245 INCHES; THICKNESS OF METAL, 0·25 INCH; RADIATING SURFACE OF EACH GROUP OF PIPES, 58·4717 SQUARE FEET.

Duration of the Experiments in minutes.	Steam pressure in the pipes in pounds per sq. inch above zero	Temperatures in degrees Fahrenheit.			Pounds weight of Steam condensed per hour, per square foot of the heat radiating surface of the steam pipes.						
		Of the steam in the pipes.	Of the air surrounding the steam pipes.	Difference of the two preceding columns.	Straw in tresses, wrapped around the steam pipes.	Bare steam pipes. (No covering of any kind.)	Pottery Pipes wrapped with straw, placed around the Steam pipes, leaving an air space between.	Steam pipes covered with cotton waste one inch thick wrapped with packing cloth and secured by strings.	Steam pipes covered with plaster 2·3622 inches thick. Plaster of the natural dark brown color.	Steam pipes covered with plaster 2·3622 inches thick. Plaster painted white.	Steam pipes covered with old felt treated with caoutchouc.
					1st Group.	**2d** Group.	**3d** Group.	**4th** Group.	**5th** Group.	**5th** Group bis.	**2d** Group bis.
60	16·523	217·96	46·40	171·56	0·139277	0·495663	0·170000	0·217108	0·253975	....	....
64	16·523	217·96	33·80	184·16	0·151566	0·485422	0·165904	0·204819	0·262169	....	....
62	18·359	223·42	33·70	189·72	0·163855	0·555060	0·186386	0·229400	0·286747	....	....
58	18·359	223·42	27·05	196·37	0·182289	0·571446	0·264217	0·286747	0·344100	....	....
60	22·031	233·17	41·45	191·72	0·245783	0·575542	0·253976	0·243735	0·319518	....	....
60	22·031	233·17	36·50	196·67	0·163855	....	0·157711	0·249880	....	0·268313	0·251928
58	22·031	233·17	36·05	197·12	0·161807	0·557009	0·178193	0·260120	....	0·266265	....
61	22·031	233·17	28·85	204·32	0·200723	0·585782	0·264217	0·328207	0·346145	....	....
52	25·703	241·60	43·25	198·35	0·243735	0·645181	0·301084	0·374819	0·389157	....	....
45	25·703	241·60	36·50	205·10	0·274458	....	0·284699	0·368675	....	0·387109	0·374819
45	29·375	249·05	43·25	205·80	0·251928	0·720964	0·270361	0·342048	0·378916	....	....
63	29·375	249·05	30·65	218·40	0·225301	0·620603	0·249780	0·327711	0·335904	....	....
Means	22·337	233·06	36·46	196·60	0·200382	0·581267	0·228878	0·286106	0·324070	0·307229	0·313373

TABLE No. 3.

Kind of non-conducting coating employed.	Absolute steam pressure in pounds, per square inch, within the cast iron pipe.	Fraction of a pound weight of steam of the absolute pressure in the preceding column, condensed by radiation, per hour, per sq. foot of cast iron, 0·25 inch thick, with natural surface in still air, by a difference of temperature of one degree Fahrenheit.	Fahrenheit units of heat radiated per hour in still air, from one square foot of cast iron, in its natural state, and 0·25 inch thick, for a difference of temperature of one degree Fahrenheit.
The bare or uncovered Cast Iron....................	22·031	0·00302422672	2·874757336690
The Cast Iron coated with common straw...........	22·337	0·00101234232	0·961813783953
The Cast Iron encased in pottery pipes coated with a mixture of loamy earth and chopped straw, around which, were wound wisps or tresses of common straw, there being an annular air-space between the cast iron and the pottery pipes.....	22·337	0·00116418239	1·106075136459
The Cast Iron coated with cotton waste, one inch thick....................	22·337	0·00145526806	1·382631592955
The Cast Iron coated with old felt treated with caoutchouc....................	23·867	0·00155996391	1·478214001296
The Cast Iron coated with the plastic composition or mortar of Mons. Pimont, 2·3625 inches thick, and of its natural dark-brown or mud color............	22·031	0·00165679755	1·574911984086
The Cast Iron coated with the plastic composition or mortar of Mons. Pimont, 2·3625 inches thick, and painted white............	23·255	0·00153873520	1·459654981866

In the condensation of steam, the heat abstracted from it is its latent heat only, the resulting water of condensation having the temperature normal to the pressure under which the condensation takes place. Now, for different pressures, the latent heat of a given weight of steam is different, becoming less and less as the pressure becomes greater and greater, but the ratio of the decrease for the latent heat is very small in proportion to the ratio of the increase of the pressure. For example: From the absolute pressure of 5 pounds per square inch to 71 pounds, the decrease in the latent heat per pound weight of steam is only 10 per centum, but if accuracy be required, it is necessary to include this difference in the calculation when the weight of steam of different pressures that will be condensed under given conditions is to be computed from the constant. The correction will be in the inverse ratio of the latent heat of steam under the absolute pressure of 22·031 pounds per square inch, to the latent heat under the pressure for which the calculation is to be made: the less the latent heat, other things equal, the more will be the weight of steam condensed. Consequently a greater weight of steam of high pressure, other things equal, will be condensed than of steam of lower pressure for a given difference of temperature between that of the steam and that of the air to which it is exposed. But although a greater *weight of steam* under these circumstances will be condensed, the *quantity of heat* lost will be only the same. In other words, the number of units of heat lost by radiation will be the same, other things equal, let the pressure of the steam or its latent heat be what it may. Hence the units of heat are not only the true measure for a particular case, but they are the universal one, being applicable to all cases, and from them the weight of steam condensable can easily be calculated for any particular pressure, the latent heat normal to that pressure being known.

An important distinction must here be drawn regarding the economic loss of heat due to the condensation of steam by external radiation, as to whether that condensation takes place in the boiler and steam-jacket of a steam-engine, or in the steam-pipe and steam-cylinder. In the first case, the loss is simply of the latent heat of the steam; but in the second case, it is of the total heat of the steam above zero Fahrenheit less the Fahrenheit temperature of the feed-water. For example: In an ordinary condensing steam-engine the temperature of the feed-water is say 100 degrees Fahrenheit, and

the pressure of the steam in the boiler is say 60 pounds per square inch absolute. The total heat of this steam above the zero of Fahrenheit is 1203 units, leaving the quantity of heat imparted to it by the fuel 1103 units, the whole of which is lost when the condensation takes place in the steam-pipe and steam-cylinder; because the resulting water of condensation is not returned to the boiler with the temperature normal to the pressure under which it was condensed. But when the condensation takes place in the boiler and steam-jacket, only the latent heat, amounting in the example to 908 units, is lost, because the resulting water of condensation is returned to the boiler with the temperature normal to the pressure under which it was condensed. In the example, therefore, the economic loss of heat by the condensation due to external radiation, is $\left(\frac{1203}{908}\right) = 32\frac{1}{2}$ per centum greater when that condensation takes place in the steam-pipe and steam-cylinder than when it takes place in the boiler and steam-jacket. It is thus apparent that even as regards the loss of heat by external radiation, a material gain can be realized by the use of a steam-jacket; and also that when a steam-jacket is used, the steam-pipe should discharge into it and not directly into the cylinder, which latter should draw its steam from the jacket. By such an arrangement nearly one-third of the fuel required to supply the loss of heat by the external radiations from the steam-pipe and from the unjacketed steam-cylinder, can be saved, even after allowing for the greater external surface of the steam-jacket than of the cylinder it protects. Of course, the narrower the annular space separating the two, the greater will be the benefit of the jacketing; which thus extends, not only to the cylinder, but to the steam-pipe when the latter discharges into the jacket. I am not aware that these facts have ever before been pointed out.

Returning now to an examination of the experimental results, we find that of the different non-conducting substances tried, the most efficient was common straw (1st Group, Table No. 2), and its application reduced the loss of heat by radiation from the bare steam-pipes 66·54 per centum.

The next most efficient non-conductor was the pottery-pipes coated with a mixture of loamy earth and chopped straw, around which were wound wisps or tresses of common straw, there being an annular air space between the steam-pipe and the pottery-pipe (3d Group, Table

No. 2). The application of this system reduced the loss of heat by radiation from the bare steam-pipes 61·52 per centum.

The third place in non-conducting efficiency was held by cotton waste, that is broken cops as they come from the machines for weaving cotton cloth (4th Group, Table No. 2). Its application in one inch thickness reduced the loss of heat by radiation from the bare steam-pipes 51·21 per centum.

The fourth place in non-conducting efficiency was held by the old felt which had been treated with caoutchouc and used on printing machines (2d Group *bis*, Table No. 2). Its application in unknown thickness reduced the loss of heat by radiation from the bare steam-pipes 48·58 per centum. The experiments with this substance being but two in number and its thickness unknown, but little use can be made of its constant with confidence.

Last in non-conducting efficiency was the plastic composition of Mons. Pimont, consisting essentially of clay mixed with cows' hair and perhaps other substances, and kneaded with water (5th group, Table No. 2). Its application in 2·3625 inches thickness reduced the loss of heat by radiation from the bare steam-pipes 45·22 per centum, the composition being of its natural dark brown or mud color.

Three experiments (5th group, *bis*, Table No. 2) were made with this composition painted white, with a view to ascertain whether its heat radiating quality was affected by color. The experiments were too few to establish the fact with certainty, but taking them as they stand, they show a reduction of 7·32 per centum in the heat lost by radiation from the same substance in its natural dark brown or mud color.

The preceding Table No. 3 shows the quantity of heat radiated per hour in still air from one square foot of 0·25 inch thick cast iron steam-pipe surface in its natural state, for a difference of temperature on the two sides of one degree Fahrenheit, when bare and when coated with the non-conducting substances hereinbefore described. The quantity of heat is expressed both in fractions of a pound weight of steam condensed, and in Fahrenheit units.

The following example illustrates the practical use of the constants in Table No. 3. Suppose an area of 100 square feet of bare cast iron 0·25 inch thick, to have upon one side an absolute steam pressure of 55 pounds per square inch, and upon the other side still air of

60 degrees Fahrenheit temperature, what weight of steam would be condensed per hour by the heat radiation from the 100 square feet of surface under the supposed conditions?

The temperature of steam of 55 pounds absolute pressure per square inch is 287 degrees Fahrenheit, and the latent heat is 912 Fahrenheit units. The difference between the temperatures of the steam and of the air is 227 degrees Fahrenheit. Then, as the constant for the bare cast iron is 2·874757336690, the weight of steam that would be condensed per hour by the surface is $\left(\frac{2{\cdot}874757336690\times227\times100}{912}\right)=71{\cdot}55392$ pounds. And the Fahrenheit units of heat that would be radiated per hour from this surface would be $(2{\cdot}874757336690\times227\times100)=$ 65256·99154.

REPORT OF THE TRIALS OF THE STEAM-MACHINERY OF THE U. S. REVENUE STEAMERS "RUSH," "DEXTER," AND "DALLAS,"*

AT THE U. S. NAVY YARD, BOSTON, MASS., IN THE MONTH OF AUGUST, 1874, BY A JOINT BOARD OF U. S. NAVAL AND U. S. REVENUE-MARINE ENGINEERS.*

In the early part of the present season there were completed for the U. S. Revenue Marine, three new revenue steamers, named, respectively, in honor of ex-Secretaries of the Treasury, the "Rush," the "Dexter," and the "Dallas." The three vessels are similar as respects the hulls, the screws, and the boilers, but the engines are different each from the other—that of the "Rush" being a compound engine; that of the "Dexter" a high-pressure condensing engine; and that of the "Dallas," a low-pressure condensing engine.

The vessels are each 140 feet long over all, 129½ feet between perpendiculars at water line, 23 feet extreme breadth of beam, and 10 feet depth of hold. The draught of water aft is about 8 feet 10 inches. The hulls are of wood. The vessels represent the smallest type of full-powered screw revenue cutters adapted for cruising pur-

*[Communicated to this JOURNAL by Chas. E. Emery, C. E.—Ed.]

poses. They were all intended to be rigged as schooners, but it having been decided to send the "Rush" to the Pacific Coast, she was rigged as a top-sail schooner. One of the vessels averaged upward of eleven nautical miles per hour for six consecutive hours on her trial trip, and neither of them averaged less than ten knots, the machinery being entirely new in each case.

Each vessel has one boiler, 11 feet wide on base and 9 feet high, with a double segmental shell, each portion being 6 feet 2 inches in diameter. There are three furnaces in each boiler, located between water legs attached to the bottom of the shell. The products of combustion return through tubes within the shell. The boiler of the "Dallas," designed for low-pressure steam, is 13 feet 9 inches long, the front connection being built in and the steam chimney attached to the boiler. The boilers of the two other vessels were designed for high-pressure steam, and are each 12 feet long, independent of front connection, which is a separate structure, bolted on. The steam chimney is also a separate structure, connected to boiler by a large tube. The boiler of the "Dallas" has 160 tubes $3\frac{1}{4}$ inches in diameter and 9 feet 3 inches long. The boilers of the two other vessels have each 158 tubes $3\frac{1}{4}$ inches in diameter and 9 feet 8 inches long.

The "Rush" is propelled by a compound engine, with vertical cylinders and intermediate receiver, arranged fore and aft at the same level, the pistons being separately connected to cranks at right angles. The cylinders are thoroughly steam-jacketed, felted, and lagged, and are, respectively, 24 and 38 inches in diameter, with 27 inches stroke of piston. The steam is distributed to the high-pressure cylinder by a short slide-valve with adjustable cut-off plates sliding on back of same. The distribution of steam to the low-pressure cylinder is effected by means of a double-ported slide-valve with lap proportioned to cut off the steam at about half-stroke. The surface condenser is arranged on the starboard side. It supports two main columns from the cylinders, and contains 900 square feet of condensing surface. The air-pump is operated from the cross-head of the low-pressure engine. The circulating pump is of the centrifugal type operated by a small engine, directly connected. The screw is 8 feet 9 inches in diameter with mean pitch of $14\frac{1}{2}$ feet. The engine was intended to be operated regularly with a steam pressure of 80 pounds, but during the trials, hereafter referred to, it was reduced to corres-

pond to the pressure carried on the trial of the "Dexter." The machinery was designed by Charles E. Emery, consulting engineer, and built by the Atlantic Works, East Boston, Massachusetts, the contractors for the vessel complete.

The "Dexter" was also built under contract with the Atlantic Works of East Boston, Massachusetts. The engine of this vessel was built from designs of that establishment, and is of the inverted type, with a single cylinder 26 inches in diameter and 36 inches stroke of piston. The cylinder is not jacketed, but is carefully felted and lagged. Steam is distributed by a short slide-valve, with adjustable cut-off plates sliding on back of same. The condenser is located outside the frame, but it and the air and circulating pumps are exact duplicates of those in the "Rush." The engine and boiler are designed to be operated with a maximum steam pressure of 70 pounds.

The "Dallas" was built under contract with the Portland Machine Works, of Portland, Maine. The engine was designed in that establishment, and is of the inverted type, with a single cylinder 36 inches in diameter, with 30 inches stroke of piston. The cylinder is not steam-jacketed, but is carefully covered with non-conducting composition and lagged. Steam is distributed by a short slide valve, with adjustable cut-off plates sliding on back of same. The surface condenser is located under starboard frames and has the same condensing surface as those in the other vessels. The air and circulating pumps are also substantially the same. The engine and boiler are designed to be operated with a maximum steam pressure of 40 pounds.

The opportunity presented of testing, in these vessels, the relative merits of the three kinds of engines attracted considerable attention. Several manufacturers and engineers expressed a desire that competitive trials be made. A correspondence on the subject was opened between the Navy and Treasury Departments, which resulted in an agreement for a trial under the direction of persons representing both services, and the undersigned, Chief Engineer Chas. H. Loring, U. S. N., and Chas. E. Emery, consulting engineer, were selected in behalf of the Navy and Treasury Departments, respectively, to make preparations for and take general charge of the trials.

When the preparations were complete, the following officers were detailed to conduct the experiments, viz.: Chief Engineer Edward Farmer, U. S. N.; Chief Engineer Geo. D. Emmons, U. S. N.; Chief

Engineer F. H. Pulsifer, U. S. R. M.; and Chief Engineer F. A. D. Bremon, U. S. R. M. As assistants to these gentlemen there were detailed Past Assistant Engineers Harvey and Cook, U. S. N.; Assistant Engineer Tobin, U. S. N., and Mr. E. Hugentobler. The care of the machinery was entrusted to the engineers of the respective vessels. The chief engineers detailed for the experiments stood regular watches with an assistant while the experiments were in progress, and at the close certified duplicate copies of the logs, which are deposited in the Navy and Treasury Departments, respectively. They also computed the principal results for their own satisfaction, and returned to their regular duties, but two of the assistants were retained to assist the undersigned in making out a statement in detail, which is presented in the annexed table.

MANNER OF MAKING THE EXPERIMENTS.

The experiments were made with the vessel secured to the wharf.

The coal, which was anthracite of fair quality, was broken on the wharf to proper size (the vessel's bunkers having been closed and sealed) and filled into bags to a certain weight.

The bags were sent on board when ordered by the senior engineer on watch, he making record on the log of the number of bags and the time of receipt; a similar record being made by one of the men on the wharf. At the end of the hour the number of bags of coal actually put on the fire was reported from the fire-room and entered in the appropriate column. The several records agreed with each other, and the total amount expended corresponded with the total number of bags filled on the wharf. The ashes were measured into buckets of which the mean weight was ascertained and tallied as they were hoisted out. They were afterwards weighed in gross on the wharf, and the two accounts found to agree substantially.

The feed-water was measured, after its delivery from the surface-condenser and before its return to the boiler, for which purpose a tank of boiler-plate was especially constructed, having a plate dividing it vertically into two equal parts.* In the upper edge of the plate was cut a rectangular notch eight inches long, by which the height to which each half of the tank could be filled was determined. The mean of the weight of water which the half tanks contained was 1129½

* [A description of this tank appears among the Editorial Items.—Ed.]

TABLE (No. 2.) Showing the Results of Experiments with the Steam Machinery of the U. S. Revenue Steamers "Rush," "Dexter," and "Dallas," made at the U. S. Navy Yard, Boston, M[illegible], A[illegible] 1874, by a Joint Board of U. S. Naval and U. S. Revenue Marine Engineers. (To accompany Report of Chief Engineer Charles H. Loring, U. S. N., senior member representing U. S. Navy Department, and Charles E. Emery, Consulting Engineer, senior member representing U. S. Treasury Department.)

No.			"RUSH."				"DEXTER."							"DALLAS."				
		Name of Steamer	"RUSH."				"DEXTER."							"DALLAS."				
		Style of Engine	COMPOUND.				HIGH PRESSURE CONDENSING.							LOW PRESSURE, CONDENSING.				
			Small.		Large.													
1	Dimensions of Engines	Diameter of cylinders ... inches	24		38					26						36		
2		Stroke of pistons ... "	27		27					36						3[illegible]		
3		Size of cylinder ports ... "	18 by 1½		2 of 27 by 1 3-16					16 by 2						33 by 2[illegible]		
4		Ratio of displacement to clearance and passages ...	.07887		.05849					.0537						[illegible]		
5	Governing dimensions of Boilers (horizontal tubular type)	Grate surface ... square feet	57.							57						57		
6		Heating surface ... " "	1572.85							1572.85						[illegible]		
7		Cross area tubes for draft ... " "	7.74							7.74						7.84		
8		Ratio grate to heating surface ...	27.58							27.58						[illegible]		
9		Ratio cross area tubes to grate surface ...	7.37							7.37						7.2[illegible]		
10	Designation of Experiments	Number for reference ...	1		2		3	4	5	6	7	8	9	10	11	12	13	14
11		Designation in log ...	Long run, Rush.		A.		B.	C.	Long run, Dexter.	D.	G.	F.	E.	L.	K.	Long run, Dallas.	I.	H.
			H. P. Eng.	L. P. Eng.	H. P. Eng.	L. P. Eng.												
12	Time	Date of experiment ... 1874	Aug. 3 to 6.		Aug. 6.		Aug. 17	Aug. 17.	Aug. 14-16.	Aug. 17.	Aug. 17.	Aug. 17.	Aug. 17,	Aug. 23.	Aug. 23	Aug. [illegible]	Aug. [illegible]	Aug. 2[illegible]
13		Duration of experiment ... hours	55		6		2.9166	1.4166	34.5	0.650	1.3166	1.200	0.9166	1.51[illegible]6	1.550	31.	[illegible]	1.7333
14	Steam Cut-off and Expansion	Average steam pressure in boiler ... lbs.	69.06	....	36.731	....	68.70	69.286	67.12	66.42	40.625	39.9	41.875	35.40	35.2[illegible]	31.[illegible]	[illegible]	27.40
15		" " " " intermediate chamber .. "		5.531	......	4.34												
16		" cut-off in fractions of stroke ...	.35995	.4652	.5976	.5292	.1827	.2335	.2483	.3331	.262	.38114	.4518	.12286	[illegible]	[illegible]	.2774	[illegible]
17		Ratio of expansion ...	2.4586	Both 6.2157	1.5948	Both. 4.0301	4.4573	3.6688	3.489	2.7239	3.3377	2.4232	2.0845	5.0674	3.8[illegible]	[illegible]	[illegible]	2.3276
18	Vacuum and Barometer	Average vacuum in condenser ... inches	26.495		26.21		25.862	25.187	25.45	25.310	26.10	26.00	25.541	26.[illegible]8	26.00	25.20	[illegible]	24.750
19		" barometer ... "	30.1757		30.147		30.195	30.195	30.143	30.195	30.195	30.195	30.195	30.080	30.080	29.997	[illegible]	[illegible]
20		" " ... lbs.	14.8122		14.798		14.821	14.821	14.796	14.821	14.821	14.821	14.821	14.755	14.755	14.7245	14.755	14.755
21	Temperatures (Fahrenheit Scale)	Air. Average temperature external air ... degrees	66.23		66.00		67.66	64.2	63.37	66.285	66.33	67.00	67.00	69.75	72.00	74.55	72.66	69.833
22		" " engine room ... "	87.86		81.23		78.428	79.6	82.27	85.428	86.00	86.00	85.66	75.25	76.80	[illegible]	75.83	73.166
23		Water. " " sea water ... "	59.96		59.615.		66.00	65.00	63.66	65.859	67.66	66.66	67.00	67.75	68.00	68.75	[illegible]	67.[illegible]6
24		" " discharge water ... "	90.56		93.77		99.857	104.8,	102.45	100.14	99.66	95.66	99.00	103.50	100.00	[illegible]	[illegible]	[illegible]
25		" " hot well ... "	110.306		108.77		115.74	121.	113.60	119.28	107.33	108.66	117.33	122.00	122.00	128.41	[illegible]	134.0[illegible]
26		" temp. feed water from tanks ... "	114.04		114.42		....	....	113.65	....	....	....	....	....	....	122.76	....	....
27	Revolutions	Total revolutions ...	233573.		19971.		9887.	5166.	126403.	2840.	4017.00	3978.	3338.	4430.	5294.	114426.	[illegible]	5809.
28		Average " per hour ...	1250.12		3328.5		3389.83	3858.35	3663.85	4369.23	3050.88	3315.00	3641.45	[illegible]	3415.48	3691.16	[illegible]8.75	[illegible]
29		" " per minute ...	70.8403		55.475		56.197	64.3059	61.0642	72.8205	50.8481	55.25	60.6909	48.6813	56.9248	61.5193	64.4792	63.4674
30	Indicator Diagrams	Average initial pressure in cyl. above atmosphere .. lbs.	67.467	8.65	35.4473	7.1842	65.613	64.590	61.4095	62.155	37.50	36.55	38.812	32.14	32.275	[illegible]	31.[illegible]5	24.566
31		" total initial pressure in cylinder ... "	82.2792	23.4632	50.2453	21.9822	80.434	79.321	79.2055	76.976	52.321	51.371	53.[illegible]	46.905	47.040	46.5832	45.8[illegible]	39.471
32		" " terminal " " ... "	29.4412	9.222	27.8506	9.1661	15.314	17.542	16.8746	21.633	13.131	15.771	19.[illegible]8	9.475	11.869	12.[illegible]0	14.[illegible]	[illegible]
33		" " cushion " " ... "	31.7332	11.1032	29.0618	8.048	7.503	8.536	8.267	10.321	6.258	8.771	9.196	[illegible]	5.194	6.1595	5.875	6.182
34		Portion stroke where cushion press. were measured ...	.8888	Full	.9005	Full	Full	Ful	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
			Maximum.		Maximum.													
35		Average back pressure in cylinder ... lbs.	9.50	3.4611	8.2305	3.415	3.1187	3.7317	3.6550	5.2710	3.1570	3.6347	4.3137	2.9730	3.3678	3.9073	4.1201	[illegible]
36		" mean effective pressure in cylinder ... "	29.6848	12.7246	18.8818	12.2997	31.439	37.1271	37.5376	42.0285	25.5826	30.6649	33.8385	18.5215	21.4471	23.5255	24.6107	24.1294
37		" " total pressure in cylinder ... "	39.1848	16.1857	27.1123	15.7147	37.8877	40.8591	41.1926	47.2995	28.7396	34.2996	38.1522	21.4945	24.8149	[illegible]	28.73[illegible]	[illegible]
38		Estimated friction pressure ... "	2.5	1.5	2.5	1.5	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.5	2.5	2.5	2.5	2.5
39	Power	Indicated horse-power (effective) ...	127.918	Both. 266.547	63.717	Both. 168.652	185.872	228.077	218.972	292.370	124.267	161.848	196.187	137.962	[illegible]	221.447	242.907	[illegible]
40		Net horse-power ...	117.145	Both. 239.432	53.0367	Both. 145.1745	169.680	205.348	201.472	271.501	109.694	146.015	178.794	119.340	[illegible]	197.915	218.137	[illegible]
41		Total horse-power ...	127.918	Both. 304.254	63.717	Both. 197.787	204.485	251.001	240.293	329.038	139.602	181.032	221.197	160.107	216.139	258.228	[illegible]	[illegible]

[Concluded on next page.]

pound [illegible] pure [illegible]
taining the vessel [illegible]
record with [illegible]
[illegible] the [illegible]
and [illegible]
two [illegible]
condenser [illegible]
[illegible]
[illegible]

The other feed pump [illegible] suction pipe [illegible] well and connected with the bottoms of the two half-tanks, through a cock on each, so that the contents of either could be drawn [illegible] discharged with the boiler.

The method of measuring the water and recording it was as [illegible]. One side having been filled, the cock over it on the receiving tank was closed and the other over the empty half opened. When the water in the full one had settled to the height of the edge of the notch, the cock in the feed-pipe was opened and the contents pumped into the boiler (care being taken to empty one in less time than it required to fill the other); when empty, its feed cock was closed. When the water in the tank, being filled, reached within a few inches of the notch, a gong in the engine-room was sounded to call attention, and when it reached the notch the gong was struck twice; at this instant the assistant engineer in the engine-room noted the reading of the counter, and the attendant in the fire-room noted and reported the height of water in the glass gauge on the boiler, as shown by a scale of inches secured to it. The attendant at the tank also noted the time of filling, and the temperature when the tank was half emptied. After entering the number of the counter in the log, the assistant engineer ascertained the numerical difference between that and the preceding entry, and if it was far from the average its cause was sought for.

By this system of checks all errors of record could be detected, and it was possible to preserve and utilize any continuous run which came to an end through derangement of the engine. All parts of the tanks, pipes and cocks were plainly visible to the eye, and had any leaks occurred therein they must have been detected. That the condensers were tight was evident from the fact that the water remained quite fresh in the boilers.

pounds, at a temperature of 72 degrees Fahrenheit. In the computations for each experiment, the weight of water is reduced to correspond with mean temperature.

One of the feed-pumps was disconnected from the check-feed valve, and its discharge pipe led to a small receiving tank placed over the two halves of the measuring tank, into which this pump forced the condensed water from the hot well. The receiving tank had on its bottom two cocks, one over each half-tank, so that either could be filled from it at will.

The other feed pump had its suction pipe detached from the hot well and connected with the bottoms of the two half-tanks, through a cock on each, so that the contents of either could be drawn out and discharged with the boiler.

The method of measuring the water and recording it was as follows: One side having been filled, the cock over it on the receiving tank was closed and the other over the empty half opened. When the water in the full one had settled to the height of the edge of the notch, its cock in the feed-pipe was opened and the contents pumped into the boiler (care being taken to empty one in less time than it required to fill the other); when empty, its feed cock was closed. When the water in the tank, being filled, reached within a few inches of the notch, a gong in the engine-room was sounded to call attention, and when it reached the notch the gong was struck twice; at this instant the assistant engineer in the engine-room noted the reading of the counter, and an attendant in the fire-room noted and reported the height of water in the glass gauge on the boiler, as shown by a scale of inches secured to it. The attendant at the tank also noted the time of filling, and the temperature when the tank was half emptied. After entering the number of the counter in the log, the assistant engineer ascertained the numerical difference between that and the preceding entry, and if it was far from the average its cause was sought for.

By this system of checks all errors of record could be detected, and it was possible to preserve and utilize any continuous run which came to an end through derangement of the engine. All parts of the tanks, pipes and cocks were plainly visible to the eye, and had any leaks occurred therein they must have been detected. That the condensers were tight was evident from the fact that the water remained quite fresh in the boilers.

The water lost from ordinary causes in the circulation to and from the engine and boiler was replaced by running hydrant water into the tank that was being filled. The additional water was therefore measured and charged in the cost.

The loss of water was not sufficient to affect the result materially in either case. It was greatest in the "Dexter," which had been on service. The safety-valve of this vessel leaked slightly, and there was probably some other trifling leak that could not be detected. The number of inches that the water fell in the boiler between the periods of supply being shown in the logs, were added together, and from the same and known dimensions of boiler the volume and weight lost were ascertained quite accurately. The reduction in the number of revolutions per tank, when the water was being received from the hydrant, furnished another and perhaps still more accurate means of ascertaining the proportionate amount lost and returned. The two methods closely agreed in fixing the loss in the case of the "Dexter" at 4·96 per cent. of the total amount of water used.

A number of indicators were tested with steam before the trials, and a pair selected for use which proved correct by a standard gauge at varying pressures. Indicator diagrams were taken every twenty minutes throughout the trials, and the data for the usual columns of the log, except the coal and ashes, every half hour.

It was ascertained that the pistons of the "Dexter" and "Dallas" were tight by removing the cylinder covers and letting on full steam pressure.

During the first and principal experiments with each vessel the boilers were worked at their maximum power with natural draft at the dock, the fires being cleaned regularly as at sea, and the cut-offs being adjusted to carry a steam pressure of about 70 pounds during trial of the "Rush" and "Dexter," and about 35 pounds during that of the "Dallas."

At the conclusion of the principal experiments on each vessel, shorter experiments, designated in the table by letters, were made to determine the effect of varying the degree of expansion at the approximate steam pressures of 70 and 40 pounds. In the case of the "Dexter" the cut-off was shortened for one experiment as much as the gear provided would permit, and for this vessel, as well as for the "Dallas," the cut-off was gradually lengthened, during other experiments, as far as the boiler would supply steam at the pressure desired.

TABLE (No. 2.) Showing the Results of Experiments with the Steam Machinery of U. S. Revenue Steamers. — Concluded.

No.	Group	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Name of Steamer	"RUSH."		"DEXTER."							"DALLAS."				
		Style of Engine	COMPOUND.		HIGH PRESSURE, CONDENSING.							LOW PRESSURE, CONDENSING.				
10	Designation of Experiments	Number for reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14
11		Designation in log	Long run, Rush.	A.	B.	C.	Long run, Dexter.	D.	G.	F.	E.	L.	K.	Long run Dallas	J.	H.
42	Water	Actual. Total weight feed water measured ... lbs.	266967.	21205.85	12944.05	7831.95	178867.	4477.31	4660.93	5605.7	5745.52	5592.79	7829.9	[illegible]	11168.02	11149.61
43		Revolutions using same	231571.	18942.	9895.00	5493.00	125197.	2752.00	3973.00	3968.00	3355.00	4437.	5310.	113750.	6156.	5847.
44		Time using same ... hours	54.482	5.69085	2.919	1.4236	34.1708	0.6298	1.3022	1.1969	.9213	1.5191	1.5547	30.8192	1.59121	1.5254
45		Water per hour per tank measurement ... lbs.	4900.103	3726.24	4434.373	5501.26	5234.505	7108.44	3579.15	4683.19	6235.93	3681.74	5036.83	5606.83	7017.30	7351.54
46		Indicated. " " " " " indicator diagrams ... "	4568.231 / 3604.00	3328.51 / 2857.56	3018.794	3932.24	3576.088	5420.24	2341.96	3019.52	3988.28	2648.88	3871.19	4442.12	5145.65	5296.16
47		Proportion of water actually used accounted for by indicator	.9323 / .7355	.8933 / .7669	.6808	.7148	.6832	.7625	.6543	.6448	.6396	.7195	.7687	.7445	.7327	.7248
48	Coal and Refuse	Total coal consumed ... lbs.	35700.				23655.5							23552.75		
49		Average coal consumed per hour ... "	649.091				685.667							758.831		
50		Coal consumed per square foot of grate per hour ... "	11.388				12.029							13.313		
51		Percentage refuse from coal	20.978				20.291							20.503		
52		Combustible per hour ... lbs.	512.925				546.538							603.247		
53	Performance of Engine	Water. Water per indicated h. p. per hour by tanks ... lbs.	18.3836	22.0943	23.8572	24.1202	23.905	24.3131	28.802	28.9356	31.7864	26.6866	26.9613	26.3447	28.9417	31.2322
54		" " " " " " by indicator "	17.138 / 13.521	19.736 / 16.9435	16.2278	17.2408	16.3303	18.5390	18.8462	18.6564	20.3290	19.2000	20.7230	20.0585	21.5958	22.7753
55		" " net " " " ... "	20.4656	25.6673	26.1337	26.2405	25.9813	26.1820	32.6284	32.0734	34.8786	30.8508	30.5176	30.1484	32.1633	34.576
56		" " total " " " ... "	16.1052	18.8397	21.6856	21.9178	21.784	21.6037	25.6383	25.8694	28.1924	22.9955	23.3014	23.1069	24.7649	25.4846
57	Performance of Engine and Boiler	Coal. Coal per indicated horse-power per hour ... lbs.	2.4352				3.1313							3.4207		
58		" " net " " " ... "	2.7110				3.4033							3.8341		
59		" " total " " " ... "	2.1334				2.8534							2.9986		
60		Combustible. Combustible per indicated horse-pow'r per hour "	1.9243				2.4959							2.7241		
61		" " net " " " "	2.1423				2.7127							3.0480		
62		" " total " " " "	1.6858				2.2744							2.3361		
63	Performance of Boiler	Coal. Water evaporated per lb. coal at observed pressure and temperature ... lbs	7.5492				7.6342							7.8632		
64		Equivalent evaporation from atmospheric pressure and temperature, 100° ... "	7.6712				7.7789							7.8458		
65		Equivalent evaporation from atmospheric pressure and temperature, 212° ... "	8.5675				8.6878							8.7625		
66		Combustible. Water evaporated per lb. combustible at observed pressure and temperature ... "	9.5533				9.5776							9.8912		
67		Equivalent evaporation from atmospheric pressure and temperature, 100° ... "	9.7076				9.7591							9.8633		
68		Equivalent evaporation from atmospheric pressure and temperature, 212° ... "	10.8420				10.8994							11.0225		
69	Calculated maximum performances based on water actually used in the different engines, but calculated for boilers of different proportions using different kinds of fuel	Coal per indicated horse-power per hour, with boilers proportioned to evaporate 9 lbs. water per lb. of coal, at pressure and temperature actually used (probably the maximum which can be obtained at sea, burning anthracite coal) ...	2.0426				2.656							2.994		
70		Coal per indicated horse-power per hour, using slow combustion in best land boilers, or best Welch coal in marine boilers, so proportioned that there will be evaporated 10 lbs. of water per lb. of coal at pressure and temperature actually employed ...	1.8384				2.3905							2.694		
71	14 Steam and expansion (repeated)	Average steam pressure in boiler	69.06	36.731	68.70	69.286	67.12	66.42	40.625	39.9	41.875	35.40	35.286	31.96	33.7	27.40
72	17	Ratio of expansion	6.2157	4.0301	4.4573	3.6688	3.489	2.7239	3.3377	2.4232	2.0845	5.0674	3.8936	3.1341	2.9858	2.3176
73	Relative performances	By comparison of combustible consumed ...	1.				1.2970							1.4256		
74		By Comparison of water used per tank measurement	1.	1.2018	1.2977	1.3120	1.3003	1.3225	1.5667	1.5739	1.7291	1.4516	1.4665	1.4652	1.5721	1.6860
75			.7690	.9243	.9980	1.0090	1.	1.0171	1.2048	1.2104	1.3297	1.1164	1.1278	1.1272	1.2090	1.2965
76			.7706	.9261	1.	1.0110	1.0020	1.0191	1.2073	1.2129	1.3324	1.1186	1.1301	1.1294	1.2114	1.2991
77			.6823	.8200	.8855	.8952	.8872	.9023	1.0689	1.0739	1.1797	.9904	1.0006	1.	1.0726	1.1508
78			.8320	1.	1.0798	1.0917	1.0819	1.1004	1.3036	1.3096	1.4387	1.2078	1.2202	1.2196	1.3081	1.4028
79			.6889	.8279	.8940	.9038	.8958	.9110	1.0793	1.0843	1.1911	1.	1.0102	1.0097	1.0805	1.1614
80			.6383	.7671	.8283	.8374	.8300	.8441	1.	1.0046	1.1037	.9265	.9360	.9855	1.0184	1.0762

October 6, 1874.

CHARLES H. LORING, Chief Engineer U. S. N.
CHARLES E. EMERY, Consulting Engineer U. S. R. M.

The long runs having demonstrated the evaporative qualities of the boilers, record was made during the short runs of the amount of water used only; from this quantity of coal necessary to evaporate it can easily be obtained. It would have been impossible to distribute properly the coal consumed during the short runs which followed each other immediately. While these runs were in progress an officer was stationed at the tanks and one in the fire-room, in addition to the usual number on watch, to avoid the possibility of error.

In the annexed table we have endeavored to show accurately, in condensed form, the results of the trials of the particular machinery described under the particular conditions named.

The actual performances will be found in lines 53 to 68, inclusive, of the table, the previous lines showing the several observed and computed quantities from which the performances were calculated.

As previously stated the boiler during the principal experiments on each vessel was operated at maximum power, and the results show that the evaporation was fully equal to that obtained in ordinary practice, but inasmuch as on land, and occasionally in steamers where space will permit, it is the practice to use a slower rate of combustion in comparatively larger boilers, thereby increasing the evaporative effect, there has been added to the table, for comparison under such circumstances, lines 69 and 70, showing the performances compared on the basis of the water actually used, but with boilers of such proportions or using such variety of coal that the evaporation will equal nine and ten pounds, respectively, per pound of coal.

The relative performances shown decimally in lines 73 to 80, inclusive, with different experiments as unity, will be found convenient for comparison.

It is believed that the other portions of the table will be fully understood without discussion or further explanation on our part.

Annexed will be found specimens of the Indicator Diagrams taken during the principal runs.

Chas. H. Loring,
Chief Engineer, U. S. N.
Chas. E. Emery,
Consulting Engineer, U. S. R. M.

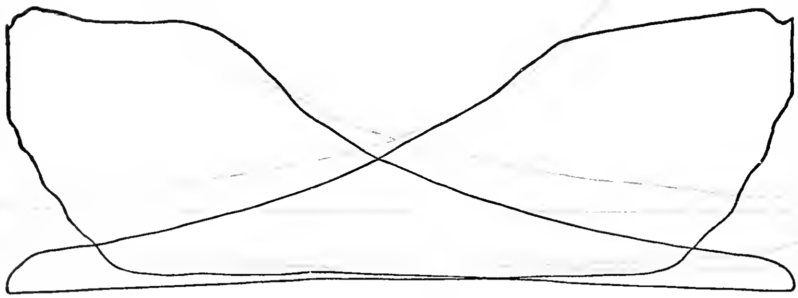
October 10, 1874.

INDICATOR DIAGRAMS.

U. S. REVENUE-STEAMER, "RUSH."

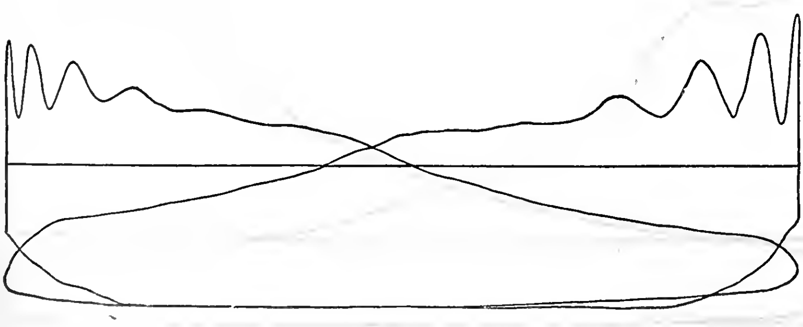
High-Pressure Cylinder.

Scale of indicator, 40 pounds per inch.



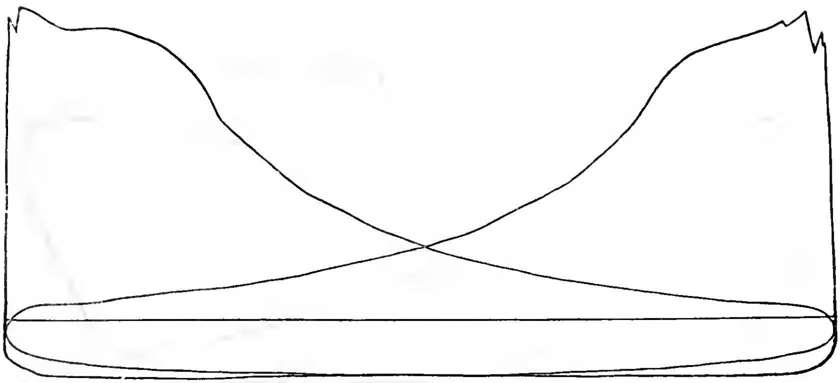
Low-Pressure Cylinder.

Scale of indicator, 16 pounds per inch.



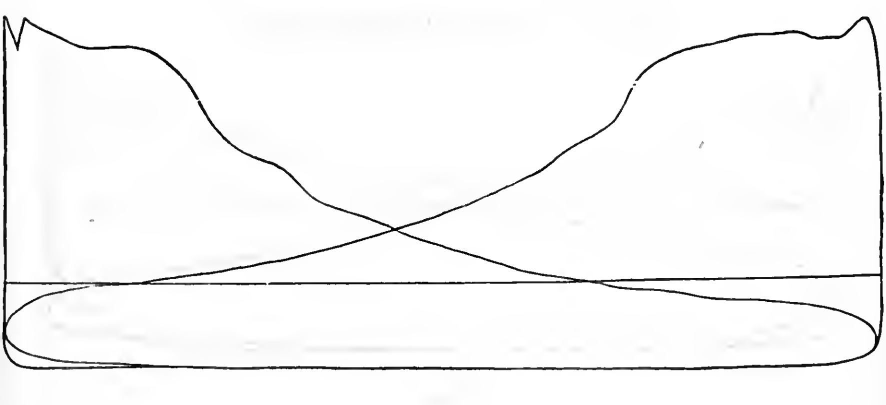
U. S. REVENUE-STEAMER, "DEXTER."

Scale of indicator, 40 pounds per inch.



U. S. REVENUE-STEAMER, "DALLAS."

Scale of indicator, 24 pounds per inch.



ON THE MOMENTS AND REACTIONS OF CONTINUOUS GIRDERS.

BY MANSFIELD MERRIMAN, C. E.,

Instructor in Civil Engineering in the Sheffield Scientific School.

I wish to put here upon record some of the results of my studies on continuous girders, which may, perhaps, prove of interest to practical engineers and bridge designers. In this article I shall take up only the commonest case, viz., girders of a constant moment of inertia, whose spans are all equal, whose supports are upon the same level, and whose ends lie free upon abutments. In designing such a continuous truss it is necessary, in order to compute the maximum strains, to know the moments and reactions at each of the supports for various assigned systems of loading. The calculation of these by algebraic work from the theorem of three moments is long and tedious, particularly when the number of spans is great, or when the truss is to be computed for many different positions of the rolling load. Especially is this true when the loads are considered as concentrated at the panel points of the truss. It is, perhaps, greatly owing to this difficulty of calculation that continuous girders have been heretofore so little used.

The moments and reactions for girders of equal span follow a law of *diverging values*, by virtue of which they may be presented in triangular tables capable of being extended to include any number of spans. From these tables these quantities at once become known, and the labor of days may thus be reduced to that of a few minutes.

I shall give the moments and reactions for the following cases: I, a uniform load over the whole girder; II, a uniform load in a single span of the girder; III, a single concentrated load in any span of the girder. These three cases can be so combined by the bridge computer as to embrace any required system of loading. The explanation and use of the tables will first be presented, and in a second article a mathematical proof of their accuracy be given.

CASE I. *A uniform load over the whole girder.* Let the length of each span be l, and the load per unit of length w. Then at any support,

$$\text{Moment} = \text{A}wl^2. \quad \text{Reaction} = \text{B}wl,$$

where A and B are constants given in the triangles below.

TABLE FOR A

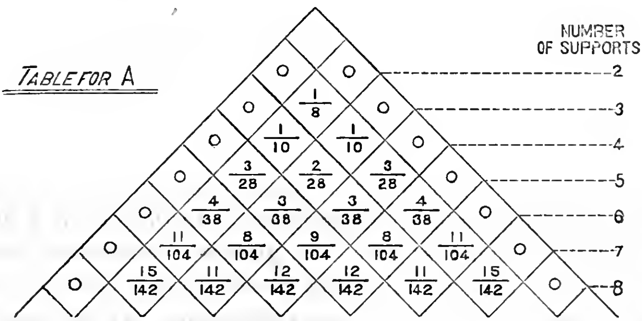
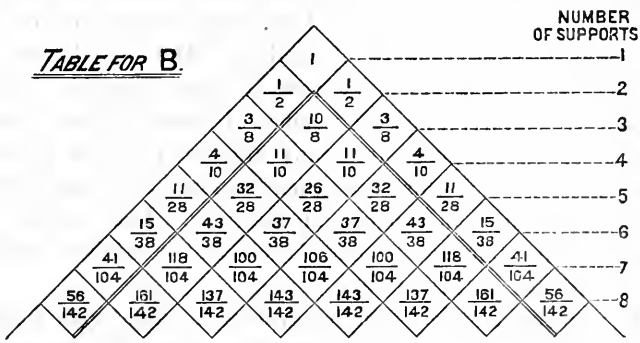


TABLE FOR B.

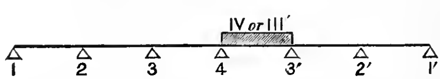


The spaces in these triangles indicate the supports of the girder. Thus, in Table B, the second horizontal line refers to a simple beam of one span, whose reactions at the two supports are $\frac{1}{2}\,wl$ and $\frac{1}{2}\,wl$; the third horizontal line indicates a continuous beam over three supports, where the reactions are $\frac{3}{8}\,wl$, $\frac{10}{8}\,wl$, and $\frac{3}{8}\,wl$ respectively.

These triangles can be extended to any required length by the application of the following law, which obtains in all *oblique columns.* The numerator of the fraction in any space corresponding to an *odd* number of supports is equal to the difference of the preceding and following numerators. The numerator for an *even* number of supports is equal to one-half the difference of those preceding and following, and the same law is true for the denominators. Therefore, to obtain a number when the supports are odd, multiply the last one

by two and subtract the number preceding; when the supports are even add together the two preceding ones. Thus, to get the denominator of the fraction for eight supports in Table A, we have $104 + 38 = 142$; to get the numerator for the second support from the left, we have $11+4=15$; for the fourth support, $9+3=12$, or, $8+4=12$. To get the quantity for the fourth support in a girder over nine supports we have $\frac{2\times11+11}{2\times142+104}=\frac{33}{388}$; or, by using the other oblique column, $\frac{2\times12+9}{2\times142+104}=\frac{33}{388}$, the same result. A single exception to this law exists in Table B; the two extreme oblique columns, representing end supports or abutments, although themselves following the above law perfectly, do not when taken in the opposite direction in connection with the other supports or piers. Hence, in extending this triangle, care should be taken to use the longest oblique columns.

CASE II. *A uniform load in a single span of the girder.* Let the supports, beginning with the abutment on the left, be numbered 1, 2, 3, etc., as far as the loaded span, and let the spans beginning on the left be I, II, III, IV, etc. Counting from the right hand end let the supports be numbered 1′, 2′, 3′, etc., and the spans I′, II′, etc. Call the moment at any support on the left of the loaded span M, on the right M′; when the moment at any particular support is mentioned it will receive a subscript corresponding to the index of the support, thus, M_3 indicates the moment at the third support from the left, and M'_2 the moment at the second support from the right hand end. In the same way the reactions are called R and R′. The reactions at the supports adjacent to the loaded span will, however, generally be referred to as R_r and R_r'. Thus a girder of six spans with



the fourth span from the right end, loaded, is shown in the figure with the indices corresponding to the above notation.

All the moments will be given by the formulæ,

$$M=\frac{D}{4c}wl^2, \text{ and } M'=\frac{D'}{4c}wl^2,$$

where D, D′, and c are constants to be taken from the following tables:

Support counted from Left. Loaded Span, counted from Right.

D	1	2	3	4	5	6
I′	0	—1	4	—15	56	—209
II′	0	3	—12	45	—168	627
III′	0	—11	44	—165	616	
IV′	0	41	—164	615		
V′	0	—153	612			
VI′	0	571	—2284			

Support counted from Right. Loaded Span, counted from Left.

6′	5′	4′	3′	2′	1′	D′
—209	56	—15	4	—1	0	I
627	—168	45	—12	3	0	II
	616	—165	44	—11	0	III
		615	—164	41	0	IV
			612	—153	0	V
				571	0	VI

To illustrate the use of these tables let us find the moments at the supports in the girder of six spans given above. For the moments on the left of the load, we look out D in the horizontal column III′; since there are six spans, C = —780, Thus

$$M_1 = 0. \quad M_2 = \frac{11}{3120} wl^2. \quad M_3 = -\frac{44}{3120} wl^2.$$

$$M_4 = -\frac{165}{3120} wl^2.$$

For the moments on the right of the load, we look for D′ in the horizontal column IV. Thus

$$M'_1 = 0. \quad M'_2 = \frac{41}{3120} wl^2. \quad M'_3 = \frac{164}{3120} wl^2.$$

c

Number of Spans.	c
1	1
2	—4
3	15
4	—56
5	209
6	—780
7	2911
8	—10864
9	40545
10	—151316

These tables may be extended to include any required number of spans by the following law, which obtains in all horizontal and vertical columns. Multiply any number by — 4, and subtract the preceding one to obtain the next required number; *e. g.*, to obtain the number at the intersection of IV′ and 4, in Table D, we have — 4(— 164) — 41 = 615, or, — 4(— 165) — 45 = 615. Also, for D and D′, we have the additional law: To obtain any number, mul-

tiply together the numbers in columns I and 2, and change the sign of the result; thus, $-(-15\times 41)=615$.

The reactions due to a uniform load in a single span are all easily obtained from the preceding tables of moments, except those at the supports adjacent to the loaded span. For the reactions at the abutments,

$$R_1 = -\frac{M_2}{l} = -\frac{D}{4c}wl, \text{ if the load is not in the first span, and}$$

$$R'_1 = -\frac{M'_2}{l} = -\frac{D'}{4c}wl, \text{ if the load is not in the last span.}$$

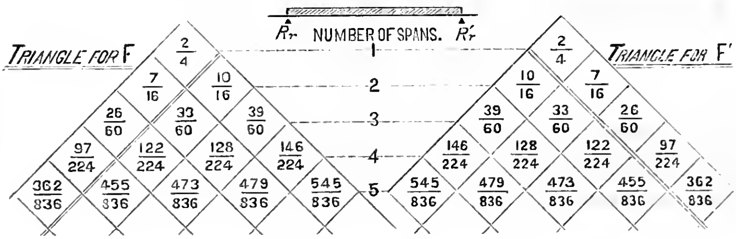
For the reactions at other supports (not adjacent to the load),

$$R = 6\frac{M}{l} = \frac{6D}{4c}wl, \text{ and } R' = 6\frac{M'}{l} = \frac{6D'}{4c}wl.$$

The reactions at the supports next to the loaded span will be given by the expressions,

$$R_r = Fwl, \text{ and } R_r' = F'wl,$$

in connection with the following tables; where the spaces indicate *spans*:



thus, if a girder of two spans have a uniform load in the first, we have at once,

$$F = \frac{7}{16} \text{ and } F' = \frac{10}{16}$$

The numbers in this triangle follow (numerically in the oblique columns) the same law as D; four times any number minus the preceding one being equal to the next following one. The first oblique column in F, and the last in F', representing abutments, vary from the law when taken in connection with the other columns, although they themselves follow it perfectly.

For example, let us find the reactions due to the uniform load in the girder of six spans given above; we have $R_1 = -\frac{D_1}{4c}wl = -\frac{11}{3120}wl.$

$R_2 = \frac{6D_2}{4c}wl = \frac{66}{3120}wl$, etc.; also, $R_4 = Fwl$, where F is found by the law from the table, or $F = \frac{4\times479-146}{4\times836-224} = \frac{1770}{3120}$, and similarly for F', $\frac{4\times473-128}{4\times836-224} = \frac{1764}{3120}$. Hence, from the above formulæ, the reactions for that case are,

$$R_1 = -\frac{11}{3120}wl. \quad R_2 = \frac{66}{3120}wl. \quad R_3 = -\frac{264}{3120}wl. \quad R_4 = \frac{1770}{3120}wl.$$

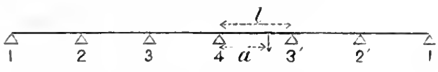
$$R'_1 = \frac{41}{3120}wl. \quad R'_2 = -\frac{246}{3120}wl. \quad R'_3 = \frac{1764}{3120}wl.$$

CASE III. *A single concentrated load in any span of the girder.* In addition to the notation previously employed I call the concentrated load P, and its distance from the nearest left hand support a. The quantity, $\frac{a}{l}$, is of very frequent occurrence and is represented by k. As in the previous case all the moments will be given by

$$M = \frac{G}{c}Pl, \text{ and } M' = \frac{G'}{c}Pl.$$

The tables on the following page give G and G′;

These tables are used exactly like those in the previous case; for illustration let us take a girder of six spans, with a load in IV or



III′. Looking for G in the horizontal column III′ we have

$$M_1 = 0. \quad M_2 = \frac{Pl}{780}(26k - 45k^2 + 19k^3). \quad M_3 = -4M_2. \quad M_4 = 15M_2.$$

Looking for G′, in the horizontal column IV, we get

$$M'_1 = 0. \quad M'_2 = -\frac{Pl}{780}(26k + 45k^2 - 71k^3). \quad M'_3 = -4M'_2.$$

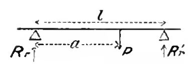
Substituting in these expressions the numerical values of $k = \frac{a}{l}$, corresponding to the panel distances of the truss in hand, the

Loaded Span, Counted from Right	SUPPORT COUNTED FROM LEFT.					
G	1	2	3	4	5	6
I′	0	$-(2k-3k^2+k^3)$	$4(2k-3k^2+k^3)$	$-15(2k-3k^2+k^3)$	$56(2k-3k^2+k^3)$	$-209(2k-3k^2+k^3)$
II′	0	$(7k-12k^2+5k^3)$	$-4(7k-12k^2+5k^3$	$15(7k-12k^2+5k^3)$	$-56(7k-12k^2+5k^3)$	$209(7k-12k^2+5k^3)$
III′	0	$-(26k-45k^2+19k^3)$	$4(26-45k^2+19k^3)$	$-15(26k-45k^2+19k^3)$		
IV′	0	$(97k-168k^2+71k^3)$	$-4(97k-168k^2+71k^3)$			
V′	0	$-(362k-627k^2+265k^3)$				
VI′	0	Etc.				

SUPPORT COUNTED FROM RIGHT.							Loaded Span, Counted from Left
6′	5′	4′	3′	2′	1′	G′	
$-209(k-k^3)$	$56(k-k^3)$	$-15(k-k^3)$	$4(k-k^3)$	$-(k-k^3)$	0	I	
$209(2k+3k^2-5k^3)$	$-56(2k+3k^2-5k^3)$	$15(2k+3k^2-5k^3)$	$-4(2k+3k^2-5k^3)$	$(2k+3k^2-5k^3)$	0	II	
		$-15(7k+12k^2-19k^3)$	$4(7k+12k^2-19k^3)$	$-(7k+12k^2-19k^3)$	0	III	
			$-4(26k+45k^2-71k^3)$	$(26k+45k^2-71k^3)$	0	IV	
				$-(97k+168k^2-265k^3)$	0	V	
				Etc.	0	VI	

LOADED SPAN COUNTED FROM RIGHT.

R_r	LOADED SPAN COUNTED FROM LEFT HAND. I	II	III	IV	V
I′	$P(1-k)$	$\frac{P}{4}(4-6k^2+2k^3)$	$\frac{P}{15}(15+3k-27k^2+9k^3)$	$\frac{P}{56}(56+12k-102k^2+34k^3)$	$\frac{P}{209}(209+45k-381k^2+127k^3)$
II′	$\frac{P}{4}(4-5k+k^3)$	$\frac{P}{15}(15-3k-27k^2+15k^3)$	$\frac{P}{56}(56-120k^2+64k^3)$	$\frac{P}{209}(209+3k-453k^2+241k^3)$	$\frac{P}{780}(780+12k-1692k^2+900k^3)$
III′	$\frac{P}{15}(15-19k+4k^3)$	$\frac{P}{56}(56-12k-102k^2+58k^3)$	$\frac{P}{209}(209-3k-453k^2+247k^3)$	$\frac{P}{780}(780-1710k^2+930k^3)$	
IV′	$\frac{P}{56}(56-71k+15k^3)$	$\frac{P}{209}(209-45k-381k^2+217k^3)$	$\frac{P}{780}(780-12k-1692k^2+924k^3)$		
V′	$\frac{P}{209}(209-265k+56k^3)$	$\frac{P}{780}(780-168k-1422k^2+810k^3)$			



$\frac{a}{l} = k$

LOADED SPAN COUNTED FROM RIGHT.

R'_r	LOADED SPAN COUNTED FROM LEFT HAND. I	II	III	IV	V
I′	Pk	$\frac{P}{4}(2k+3k^2-k^3)$	$\frac{P}{15}(7k+12k^2-4k^3)$	$\frac{P}{56}(26k+45k^2-15k^3)$	$\frac{P}{209}(97k+168k^2-56k^3)$
II′	$\frac{P}{4}(6k-2k^3)$	$\frac{P}{15}(12k+18k^2-15k^3)$	$\frac{P}{56}(42k+72k^2-58k^3)$	$\frac{P}{209}(156k+270k^2-217k^3)$	
III′	$\frac{P}{15}(24k-9k^3)$	$\frac{P}{56}(48k+72k^2-64k^3)$	$\frac{P}{209}(168k+288k^2-247k^3)$		
IV′	$\frac{P}{56}(90k-34k^3)$	$\frac{P}{209}(180k+270k^2-241k^3)$			
V′	$\frac{P}{209}(336k-127k^3)$				

moments due to every position of the rolling load in this span become known.

The law for the extension of these tables is apparent upon inspection. The coefficients of k, k^2, and k^3 increase vertically by the law of multiplying each number by four and subtracting the preceding one. The coefficients of the parentheses increase horizontally by the same law, and their signs alternate.

The reactions become known by formulæ and tables similar to those of the preceding case. For the reactions at the abutments,

$$R_1 = -\frac{M_2}{l} = -\frac{G}{c}P, \text{ and } R'_1 = -\frac{G'}{c}P.$$

For all the other reactions except those at the supports adjacent to the loaded span,

$$R = 6\frac{M}{l} = 6P\frac{G}{c}, \text{ and } R' = 6P\frac{G'}{c}.$$

The reactions at the supports adjacent to the loaded span would be best presented to the eye by triangles similar to those used in the last case, but for convenience in printing they will be given in tables like those used for the moments.

The spaces in these tables represent spans; by following the oblique lines the values may be taken out as in the triangles; thus all the quantities beginning with $\frac{P}{56}$ belong to a girder of four spans. Or, without considering the number of spans, the reactions may be determined by the number of the span counted from each end. Thus, if a load be on the second span from the left and fourth from the right, the reactions adjacent to the loaded span are found in the spaces at the intersection of II and IV′.

These tables follow, in the horizontal and vertical columns, the law of multiplying each number by four and subtracting the preceding one to obtain the next following number. As before it is to be noticed that the first vertical column for R and the first horizontal column for R′, representing the reactions at the abutments, do not conform to the law when taken in connection with the others, although they themselves follow it exactly.

	q
q_1	α
q_2	β
q_3	$4\beta - \alpha$
q_4	$15\beta - 4\alpha$
q_5	$56\beta - 15\alpha$
q_6	$209\beta - 56\alpha$
q_7	$780\beta - 209\alpha$
q_8	$2911\beta - 780\alpha$
q_9	$10864\beta - 2911\alpha$
q_{10}	$40545\beta - 10864\alpha$
	Etc.

If it were desired to use these tables for the calculation of a continuous girder of a great number of spans, say twenty, it would by no means be necessary to compute all the intermediate values to obtain the quantities for that case. The extension of a single oblique column, or most two, will always be sufficient, in connection with the following table of multipliers. If a series of numbers follow a law such that each one is equal to four times the preceding, minus the next preceding, they will be represented by the following table, where α and β are any two such numbers, and q_1, q_2, q_3, etc., the successive numbers beginning with α. This table may be made out once for all, since the co-efficients of α and β follow the above law. For instance: To obtain from table F the moment at support 3, due to a uniform load in span III, for a girder of twenty spans, we have $\alpha = 39$, $\beta = 128$ for the numerators, and $\alpha = 60$, $\beta = 224$ for the denominators, and the corresponding quantities will be determined by substituting these values in q_{19}. Tables A and B may be extended in this way, since the quantities corresponding to even numbers of spans follow this same law, as also do the odd spans.

I might also give tables like the above which would give the moments and reactions due to a uniform load over a part only of a single span. Should they be required they can be obtained in every case from the formulæ for a single concentrated load by putting P equal to wda, and integrating the expressions between the desired limits. Tables following the same law of diverging values could also be given for the inflection points, and the maximum deflection in every span, but would be of very little practical value. The moments and reactions alone are sufficient to fully compute any truss. The former divided by the depth of the truss gives the chord strains over the supports; the latter determine the shearing force at every cross section. From these the strains in all the other members may be easily found either by algebraic or graphical methods for the proper cases of loading.

In the next number of this JOURNAL I propose to give a strict mathematical demonstration that the above laws and formulæ hold true for all continuous girders of the class considered, and by which anyone may test the accuracy of the tables here presented. I shall also investigate and present simple formulæ and tables for the case where the two end spans are different in length from the other spans, the ends being either free upon abutments or firmly fastened, so that the tangent at that point is always horizontal.

THE NEW PAVILION WARD OF THE PRESBYTERIAN HOSPITAL OF PHILADELPHIA.

By JOSEPH M. WILSON, C. E., Engineer and Architect.

The Presbyterian Hospital of Philadelphia has now nearly completed a new Surgical Pavilion Ward on its grounds at Thirty-ninth Street and Powelton Avenue, and as the plan and arrangement are a considerable departure from the old established and time-honored principles of hospital construction, a short description may be of interest.

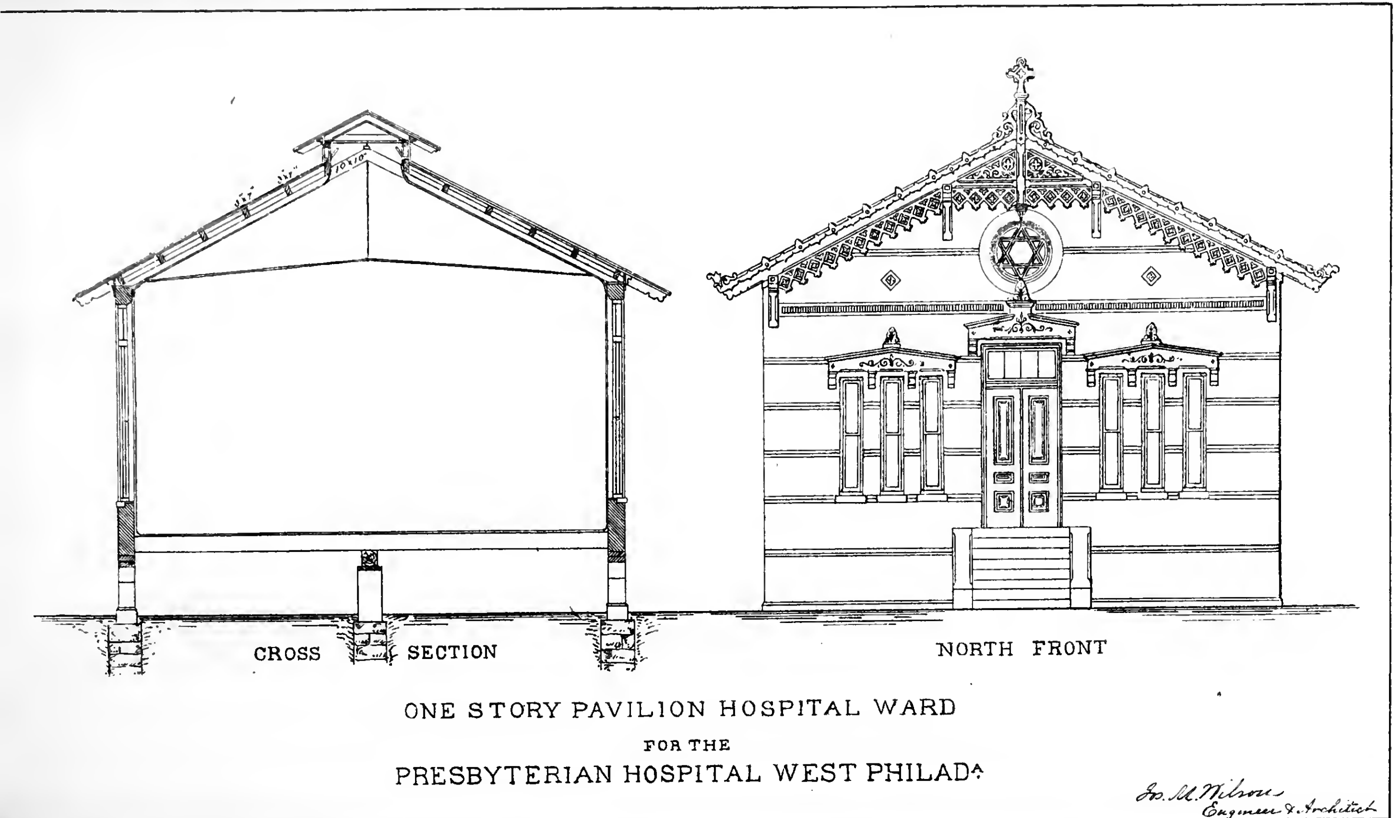
The principles of the arrangement are based on those of the United States Temporary Military Hospitals erected during the late war, and afterwards extensively adopted in Germany during the Franco-German War, and also to a greater or less extent, made use of in some of the later European permanent constructions.

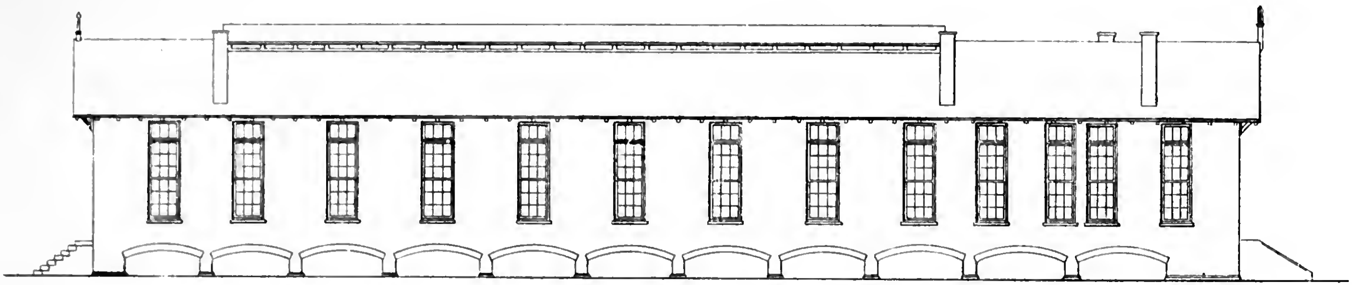
The building, as shown by the accompanying plan, consists of only one story, and is comprised in a rectangular space of 32 feet by 143 feet, its position lengthwise being nearly north and south. It contains the following apartments: A sitting-room of 30 by 16 feet at the south end, communicating directly with a ward-room of 30 by 88 feet, the latter having a capacity of 28 beds. From the north end of the ward-room a hall of 6 feet in width connects with an entrance from the street at the north end of the building. On the west side of this hall are arranged the operating room, $11\frac{1}{2}$ by 16 feet, and the nurses' room $11\frac{1}{2}$ by 14 feet, the latter having a large linen closet $11\frac{1}{2}$ by 5 feet attached to it. On the east side are the baths and

lavatories and water-closets, and a special diet kitchen of $11\frac{1}{2}$ by 10 feet.

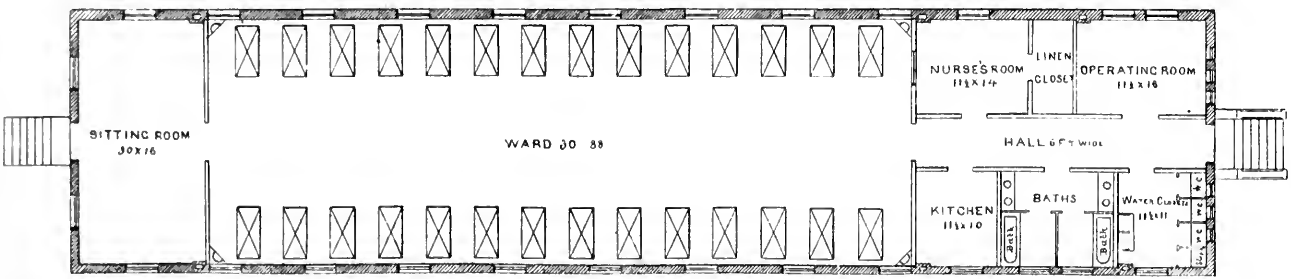
The foundations of the building are of stone. The floor is raised to a level of 5 feet above the ground, and the space underneath left open to the free circulation of air by means of arches in the brick walls along the sides of the building, the area of ground contained within being covered with a good asphalte pavement, so as to prevent any moisture arising from it. The ground around the building is well sloped off so as to drain all water away from it. The exterior walls are of brick, 13 inches thick, and built hollow.

The north, or street entrance, is of pressed brick, with courses of colored brick and Ohio stone dressings, the entrance steps being of granite. Particular care has been taken in building the walls that no opportunity shall be afforded for moisture to get through from the outer to the inner portions of the wall. Between every window, and near the level of the floor, small openings are made from the exterior to the inner air space of the brick walls, with little iron doors to them that may be opened or closed at pleasure. These openings all have permanent wire screens to prevent entrance of vermin. At the top of the wall the air space communicates with the space between the roof sheathing and plastering by a series of openings corresponding with the lower ones. The walls are 15 feet high in the clear from top of floor. The floors are laid with best quality Carolina pine boards, in very narrow widths, tongued and grooved, and put together with white lead, so as to make a thoroughly water-tight job, the spaces between the joists underneath being boxed and filled in with mortar concrete close up to the flooring. The windows are made of double glass, with an air space of $\frac{1}{2}$ inch between them. Each window has an upper and lower sash, that may be raised or lowered, and a swinging transome above. The window sills are of slate. Under each window in the inner face of the wall an opening is made communicating with the inner air space of brick work and fitted with a register that may be opened or shut as desired. The ward room ceiling is finished off on the slope of the roof and is provided with a ridge ventilation for its whole length. Small openings are made up under the ridge ventilators into the space between the plaster and sheathing about every 12 feet, so as to allow of circulation of air through the entire air spaces of wall from the previously mentioned openings below. The ceilings of the other rooms are


10"x10"
CROSS SECTION
NORTH FRONT
ONE STORY PAVILION HOSPITAL WARD
FOR THE
PRESBYTERIAN HOSPITAL WEST PHILADA.
Jo. M. Wilson
Engineer & Architect



LONGITUDINAL ELEVATION.



MAIN FLOOR

Photo & Printed by J.H. Camp 69 Jayne St. Philad^a

horizontal and at a height of 15 feet from the floor. All of the inside doors except the one to the water-closet have transomes, swung on centres.

The plastering is in three coats, troweled down to a thoroughly smooth hard finish, and as soon as perfectly dry in every respect it will be painted.

The roof is covered with slate.

In finishing up the interior work especial care has been taken to make everything as plain as possible; no mouldings, no grooves or ledges to catch and hold dust, but every necessary projection rounded off and made smooth. The doors are not paneled but are made perfectly plain, of tongued and grooved boards in two thicknesses, without beads. The plastering has been rounded at the ceilings, the windows, the angles of the rooms, etc., there being no sharp corners. It is finished at the bottom next to the floor in Portland cement, and there are no washboards. All of the inside woodwork is rubbed down smooth and finished with linseed oil and shellac. The floor is oiled in two coats linseed oil well rubbed in.

A small range is placed in the special diet kitchen, and has connected with it a large circulating galvanized iron boiler to supply bath tubs with hot water.

The building is heated by a hot water circulating apparatus.

A small cellar is placed in the southeast corner of the building, under the sitting-room, and also one in the northwest corner under the operating room, each being 16 feet square. In each of them a boiler will be placed, with radiating pipes carried through the different rooms. Four open grates are placed in the four corners of the main ward, entirely for ventilating purposes.

The plans were prepared by the Engineer and Architect, under the direction of the Building Committee, the gentlemen who composed it being indefatigable and enthusiastic on the system adopted, and any merits the plan may possess are justly due to them.

Chemistry, Physics, Technology, Etc.

NEW PROCESSES IN PROXIMATE GAS-ANALYSIS.

By Professor Henry Wurtz, of New York.

[*Communicated in part, with Experimental Illustrations, to the American Gas-Light Association, October* 22, 1874.]

(Continued from Volume lxix, page 155.)

The soda-pencils are cracked up, a few at a time, by gentle blows in a mortar, to lengths of from ·5 to ·7 inch. This is very rapidly and easily effected; but still a film of moisture is absorbed; and I have found that desiccated gas will then take up from it a trace of water. The precaution is therefore taken to append a small CaCl tube to the second of the two, M. This may be avoided if the Preparatory Train, Fig. 2, be employed to dry out these soda-tubes, before their initial weighing.

The Meter and the Measurement Thereby.—This most essential operation of all, is effected with every precaution to insure known conditions of the residual gas. In the case represented in Fig. 1, it is to be understood that a dry meter is used to measure the gas as absolutely freed from moisture, and at, or as close as possible to, the temperature of melting ice. Within N, filled with cracked ice, is coiled some feet of rubber tubing—well *glycerated* internally—and the meter is enclosed—leaving the dial exposed—in an outer casing, not here shown, filled with feathers, or better, with *ice*. In an emergency, muffling the meter in blankets has been resorted to.

The meters used must of course be most carefully tested and their average errors determined and taken note of. Space cannot, unfortunately, be here spared to explain the modes of effecting this. As it may often be necessary to use wet meters, like those usually found in photometric rooms, I have represented in Fig. 4 a modified mode of measurement, which admits of such use. Here also the whole meter, except the dial, ought to be protected, as before, from external warmth.

It will be readily understood that when the photometric meter—which usually registers but four feet in one revolution—must be employed, appropriate measures must be taken to mark, or to verify in some sure way, the number of revolutions, when these are desired, or are likely to exceed two revolutions in all. In Fig. 1, as I ought further to explain in this place, the eduction-tube O, which is the prolongation of the coil in N, passes to the inlet-aperture of a *dry* meter, and not, as in Fig. 4 below, to the rear of a wet-meter drum.

II. Of the Preparatory Train. (Fig. 2.)

This is employed in the initial drying-out of the apparatus, preparatory to the first weighings; and also for the final completing of the separation preparatory to the last weighings; in the latter case, by the distilling or transferring over, in a current of pure dry gas, of the liquids that condense, by mere refrigeration and adhesion, in the first tubes.

It is made up as follows: Stop cock A, in an induction-tube from any service-pipe bringing street-gas; test-tube B with inlet-tube passing to its bottom, which contains a strip of turmeric paper, to indicate (qualitatively) ammonia; two U-tubes C and D, containing respectively granulated fused bisulphate of potash and granulated blue vitriol; a second test-tube E, containing slips of both turmeric and lead-paper, to demonstrate the complete removal by D and E of the HS and NH^3 (the latter by comparison with the turmeric paper in B); a CaCl tube F: and a sodic hydrate tube H (of large dimensions, as shown, in cases where the street-gas, through iron-purification or otherwise, contains very much CO^2). [B, in this train, is not at all essential.]

In this figure the Preparatory Train is represented as attached to the first compound member (marked A′) of the train for analysis of purified gas, shown in Fig. 4. In Fig. 3, H represents the final member of the preparatory train; showing its connection with the train in Fig. 1, during the distillation preparatory to the final weighings.

It may be stated that this preparatory train being required only to furnish a current of gas free from moisture and impurities, it is obvious that the current that issues from one analytical train while in operation, is suitable for the preparation, for either initial or final weighings, of another analytical train, and that this circumstance

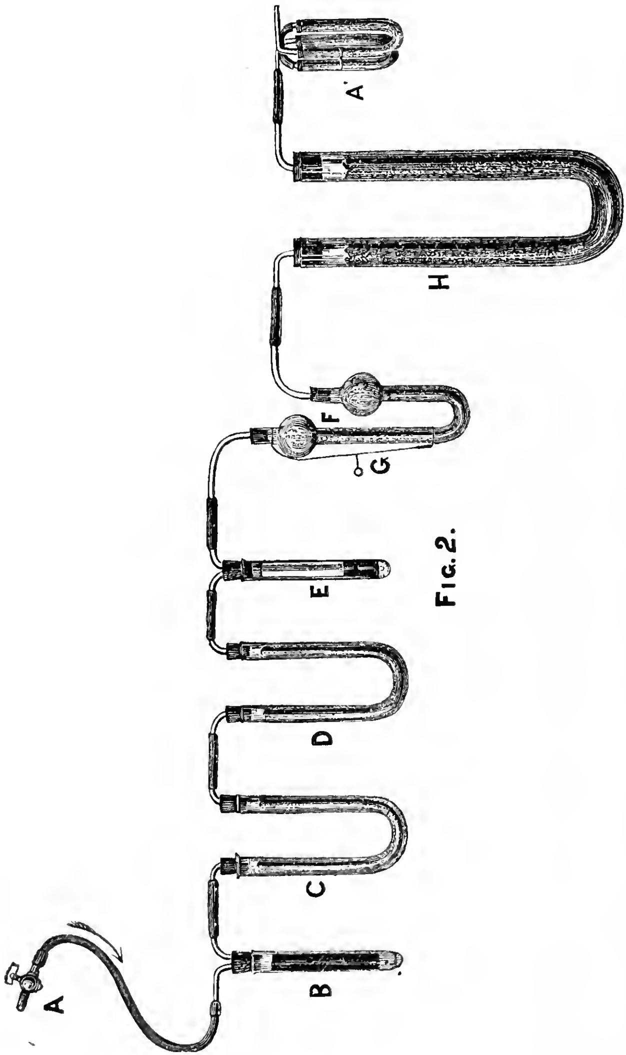


Fig. 2.

Supplementary or Preparatory Train; Both for Preliminary Preparation of the Trains for Analysis, and for Completion of the Processes therein.

will at times be available, and lead to saving of trouble in transportation and erection of apparatus.

Another important point of practice with the preparatory train, demands a few words. Its union with the analytical train represented in Fig. 1, makes a long and very tortuous passage for the gas, which necessitates an important *pressure* to force a rate of flow sufficient for rapid work. This is very liable to cause difficulty, with street-gas, particularly during the midday hours. It will therefore often be advisable to arrange so as to conduct preparatory operations during the night hours. Cases occur in which special expedients may be necessary to procure a sufficient flow. A small gas-holder, when available, may be used. The pressure in the mains between the exhauster and the purifiers will always be ample to force one or even two cubic feet per hour through almost any length of (unobstructed) train; but in this case it must be remembered that the preparatory train should possess an extra size and power, and be properly proportioned, to take out the large proportion of impurities present; for if a preparatory train left working with an analytical train overnight should become fouled, of course the whole apparatus would be liable to be rendered useless, and the whole time and labor be lost

It may be scarcely necessary to suggest that for these preparatory operations, coal-gas is used only for conveni nce, With a holder, or an aspirator, a stream of *air*, similarly freed from water, ammonia, carbonic acid, etc., is generally equally applicable, and when the pressure has to be assisted, we may in most cases just as well use air, if we have the appliances.

III. Of the General Manipulations with Crude Coal-Gas.

In addition to the details which have been given when describing singly the members of the train in Fig. 1, further explanations are needed, especially with regard to the application of the preparatory train thereto. In the preliminary preparations for the *initial* weighings, it it unnecessary, with the arrangement as here represented, to attach more than the first four pieces, to and including the bisulphate tube G, for reasons which will be obvious without explanation. Some five or six cubic feet of gas transmitted from a preparatory train, will dry out these first four members sufficiently to allow of correct weighing. This will be accomplished by setting and keeping the apparatus at work during one night, say from 5 P. M. till 8 A. M.,

or 15 hours, at the rate of about 0·3 or 0·4 foot per hour. The rate of flow is readily regulated by a few observations, of ten minutes each, of a meter at the tail of any train. A little practice enables the rate to be judged of closely enough, by the size of the flame burning from a small straight glass tube at the tail of the apparatus, as shown in Fig. 4.

The preparation for the final weighings is here the important part, and indeed the only troublesome part of this analysis. Fig. 3 repre-

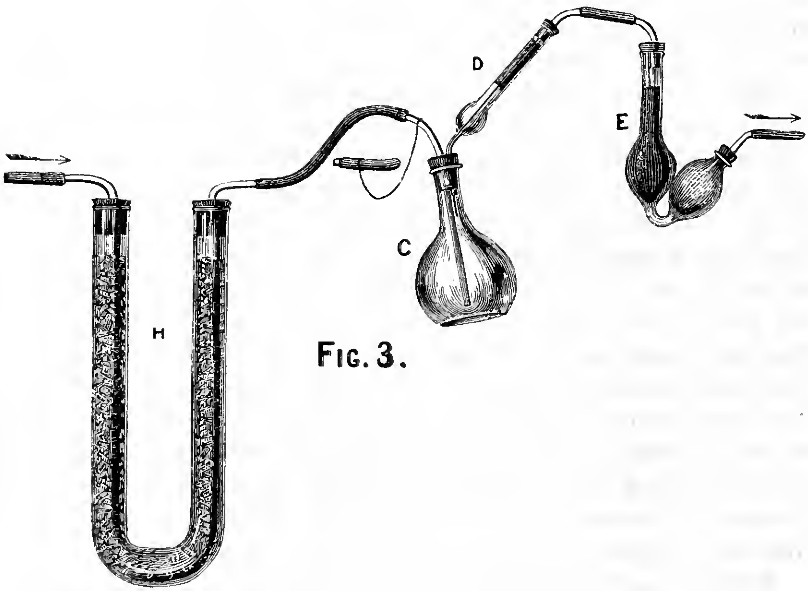


FIG. 3.

Supplementary Arrangement for Completion of Process in the Train, shown by Fig. 1.

sents, as aforesaid, the mode of attaching the preparatory train to Fig. 1, for this final operation, or rather succession of operations. D here represents a new tube introduced at this time, which is an ordinary form of CaCl tube, but having its smaller extremity bent at an obtuse angle, as shown, and which contains near its upper end a slip of turmeric paper, and has, moreover, running through it from end to end, and projecting an inch at each end, a *small flexible copper wire;* the object of which latter is to clear a passage through the crystals of naphthaline which condense in this tube at a subsequent stage of operations.*

* This wire should have been shown more distinctly in the cut, but this is only one of several unfortunate defects in these cuts.—H. W.

After this disposition of the apparatus has been made—D having been of course *weighed* with its appendages, and the jar of ice N (which is no longer of use) removed, the meter being connected directly with M—the first step is to distill over, at a very low temperature (unless saving of time is important, at ordinary temperatures) in the current of gas from the preparatory train—which generally in this case may flow even as rapidly as two feet per hour—all the volatile ammonic carbonate and sulphohydrate that has condensed in the flask C and cotton tubes E and F. The volume of gas required to effect this may be double (or even more) that from which the liquid was condensed. It ought to have been stated that the total amount of crude gas analyzed by this apparatus should not exceed ten cubic feet. This volume is within the limits of manageability, but generally somewhat less is probably advisable. With a rapid current of gas, this complete transfer of the volatile ammonia-compounds will be found to have been effected during 15 or 18 hours; but sometimes more time is required; and it is better to allow 24 hours for this part of the process. If an attempt to hasten it is made, by immersion of the flask in warm water, constant watching is necessary, as naphthaline then enters upon the scene, and may at once clog up all passage. The complete transfer of the ammonia is indicated by the return of the slip of turmeric-paper to its natural color. As, in my experience so far, this liquid *always* contains chloride of ammonium, and possibly sulphite and other non-volatile ammonia salts, those who wish to transfer *all* the ammonia to the bisulphate-tube G, must introduce into the flask a weighed quantity of dry hydrate of soda.

When the ammonia-transfer has been completed, the flask C is immersed—the gas-current being continued—in water sufficiently hot to volatilize the naphthaline, which will condense in crystalline form, together with water, in the tube D. The wire running through D now comes into play; and, in fact, without it, naphthaline would here become as great a cause of difficulty as it often does in the distribution of coal gas. When clogging occurs, the gas-current is stopped, the rubber connector between D and E detached, and the wire moved up and down or twisted round. With careful management, two hours work and some two feet of gas from the preparatory train, will suffice to transfer the naphthaline to D, which is then detached and weighed again. To remove the intermixed water from the naphthaline, the lower end of D is stopped, the cork and tube removed from the upper

end, the wire coiled within, and this upper end connected by a wide short rubber-connector with the open end of a test tube containing some granulated CaCl. When dry, the cork and tube are restored, the stopper removed, and the weight again ascertained; the variation now from the first weight is the naphthaline, so far as it can be saved by this mode; which of course is imperfect, but is the best that I have so far succeeded in devising.*

The flask C, still containing tar and water is then removed likewise from the arrangement—the stoppers DD (Fig. 1.) being applied —and then H of the preparatory train is connected directly with the first cotton-tube E; the gas-flow being resumed. Some five feet more of dry gas may be now required to transfer all the moisture to the CaCl tube between G and H (omitted from the cut.) The water and tar in the flask C must be separated by careful distillation at a very moderate temperature, and in estimating the weight of the residual tar, account must be taken of the sodic hydrate that was added, as above, to eliminate the fixed ammonia.

The point at which the whole train becomes dry and ready for the final weighings, is readily perceived by a practiced eye. One indication is a faint superficial whitening of some unaltered blue granules (if any) of cupric sulphate in the tube HJ. Several other indications might also be cited.

IV. Of the General Manipulations with Purified Coal-Gas.

Fig. 4 represents a very complete train for this purpose. As the suspended matter here is absent or trifling in amount, and the ammonia usually very small, A represents a combined arrangement for taking up both these. The first or right hand U-tube is loosely filled with cotton, the second one with granular bisulphate. E contains two slips, of turmeric and red litmus paper, to verify the perfect efficiency of the bisulphate. F contains granulated cupric sulphate crystals. G is CaCl. H is sodic hydrate, with a small CaCl-tube appended. The arrangement KL, for determining oxygen, requires special explanation. K contains glass beads or broken-up glass rod, wet with a concentrated solution of pyrogallol in previously-boiled water. L contains CaCl. As, in order that the pyrogallol should

* Since the above was first presented to the Gas-light Association, I have discovered that very appreciable additional traces of naphthaline condense, and remain throughout the final desiccation, in the cotton-tubes E and F, and have therefore been rated as solid matter mechanically suspended.—H. W.

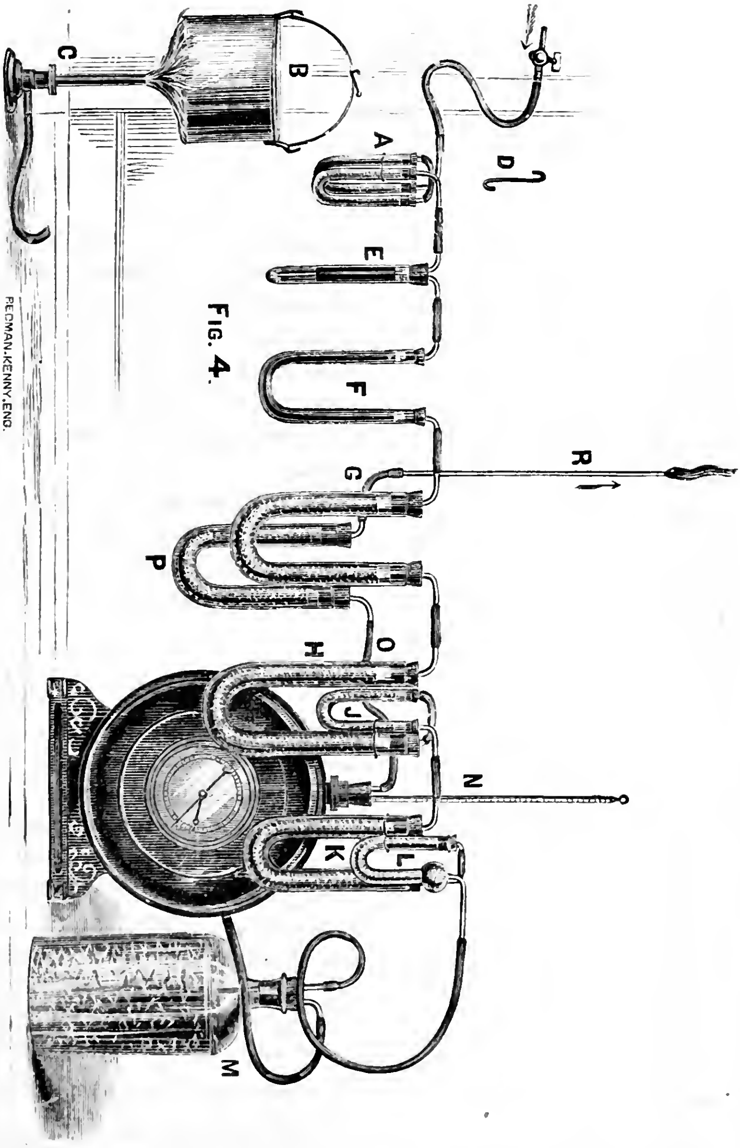


FIG. 4.

TRAIN FOR THE ANALYSIS OF PURIFIED COAL-GAS, ETC.

take up the oxygen, there must be an alkali present, the following special course is adopted for preparing KL for initial weighing and introduction into the train. K is immersed, L being detached for the time, in snow and salt; and connected with a flask like C in Fig. 1, containing some of the strongest liquid ammonia. A current of common street gas is then directed first into the ammonia flask, then through K. The former is warmed, and the as gas, it issues from the latter, lighted. The point of saturation of the contents of K with NH^3 will be indicated by a change in the character of the flame. The ammonia-flask is then detached, K being simultaneously—to prevent ingress of air—attached to J, L replaced, and the whole put in position.

A, in connection with E, is also dried out before initial weighing of the former, by a current from the Preparatory Train; this operation being greatly accelerated in this case, by immersion of A in the boiling water in B, which is raised up and hung, for this purpose, on the little wire pothook D. It is to be observed that the two tubes in A are weighed separately, and not together; and to avoid hygroscopic moisture, cooled and enclosed while weighing, in close boxes of sheet-brass or tin. The members of this train G, H, and P require no preparatory desiccation before weighing.

With reference to the tube P, a special remark should be made. The *hygrometric* equilibria of the cupric sulphate in the aerial and the gaseous media respectively, may appreciably vary, even at the same temperature. A safe plan, therefore, before initial weighing of this tube, will be to pass through it a current of the gas to be analyzed, for a few minutes. This will serve also as a useful qualitative test, in advance, of the amount of H S present.

When the H S is very minute, as it should be in a well-purified street-gas, there is another method available, which I have often used, and which may be preferred, as surer. I find if the granulated blue-vitriol be spread out in a gentle sand-bath heat, for some days, it loses most of its water, turning white and chalk-like, without falling to powder, and will now still absorb H S readily, even though the latter be absolutely dry. If F be charged with such dehydrated cupric sulphate, it may be introduced after the CaCl-tube G, instead of before, and will there absorb from the gas only H S. If it has lost as much as three-fifths of its water, it will not impart any moisture to the gas at ordinary temperatures.

(To be Continued.)

FORMULÆ FOR THE APPARENT SPECIFIC HEAT OF SATURATED VAPORS.*

By P. P. Poinier, Post Graduate Course, Stev. Ins. Tech., Hoboken.

It has long been admitted by engineers that when high rates of expansion are used the steam jacket effects a saving of fuel. The most plausible theory advanced to account for this saving is, that the hot steam in the jacket prevents in a measure that cooling of the cylinder indirectly due to the work performed. The details of this theory are of course familiar to all engineers, the most important supposition being, that just enough heat is furnished by the jacket to prevent any of the expanding steam from liquefying, and the argument alleged in its support, that wet steam is a very good, while dry steam is a very poor conductor of heat.

Whatever may be the defects of this theory, it seems to be the most generally accepted one; in comparing, therefore, the experimental saving with that deduced from this theory, the quantity to be calculated is the amount of heat necessary to prevent a certain quantity of saturated steam, expanding between given limits, from liquefaction.

The fundamental fact, that, steam expanding in a cylinder without receiving or emitting heat would undergo liquefaction in consequence of the external work performed was first definitely signaled by Professor Rankine.

In a paper read before the Royal Society of Edinburgh, on the 4th of Feb., 1850, he gave the following formula for the apparent specific heat of saturated vapor:

$$K_s = \frac{1}{CnM}\left(\frac{1}{N}+1-\frac{\beta^1}{\tau}-\frac{2V^1}{\tau^2}\right) \text{ numbered } \quad (30)$$

in which C denotes the absolute temperature of melting ice, *i. e.*, 273°

[*We have received the accompanying paper from Prof. Thurston with a memorandum to the effect that the treatment so neatly carried out by the author, gives the reader of Thermo-dynamics a new and very convenient expression which may be used in deducing the amount and effect of condensation within the steam cylinder due to the expenditure of energy. This, like the paper of Mr. Henderson, Class of '74, is supplementary to a portion of the work of Rankine and Clausius, and not merely a new rendering of old methods.

The value of such new conceptions and methods in the science of Thermo-dynamics is a sufficient excuse for its publication, and one which will be appreciated even by non-mathematical readers.—Ed.]

Cent., 493·2° Fahr., n the number of molecules of the substance which occupy unity of volume under standard pressure, when in the state of perfect gas; M the "total mass of one molecule;" N such a quantity that $\frac{1}{\text{CnMN}} = \mathfrak{K}$, the actual specific heat of the substance in the state of perfect gas; and β^1 and γ^1 constants entering the expression,

$$\log_e \mathrm{P} = a - \frac{\beta^1}{\tau} - \frac{\gamma^1}{\tau^2}.$$

τ being the absolute temperature on the air thermometer.

Immediately afterward he wrote:

"For the vapors of which the properties are known, the negative terms of this expression exceed the positive, at all ordinary temperatures, so that the kind of apparent specific heat now under consideration is a negative quantity."*

While this formula is less adapted to computation than some that have since been proposed, it is still of historic interest as having been the original expression of an important discovery.

A month later Clausius published† his first *memoire* on the "Moving Force of Heat." Applying first the law of Mayer and Joule, and then the principle of Carnot, he established the two following equations:

$$\frac{\mathrm{dr}}{\mathrm{d}\tau} + \mathrm{C} - \mathrm{h} = \mathrm{A}(\mathrm{s} - \sigma)\frac{\mathrm{dp}}{\mathrm{d}\tau} \qquad \text{numbered III.}$$

$$\text{and } \frac{\mathrm{dr}}{\mathrm{d}\tau} + \mathrm{C} - \mathrm{h} = \frac{\mathrm{r}}{\tau} \qquad \text{numbered (32).}$$

In these equations r represents the latent heat of evaporation of the substance; C the specific heat of the liquid; h the specific heat of the saturated vapor, corresponding to Rankine's K_s; A the thermal equivalent of energy, that is 1·424 in French, or 1·772 in English units; p the normal pressure per unit of surface, and (s — σ) the increase of volume accompanying evaporation, which, in the case of water, may without sensible error be written v, the total variable volume.

Equation III embodies a method which is suggested by an equation in Rankine's Steam Engine and other Prime Movers, although

*Trans. Roy. Soc. Edin. vol. xx, p. 171.

†Poggendorff's Annalen, 1850, series iii, vol. xix, p. 368.

no direct reference is there made to it.* The simplest method, however, of calculating h or K_s, when the limits are given as temperatures, is derived by means of the principle of Carnot, for in a "Carnot's cycle."

$$Q = \tau \frac{dQ}{d\tau},$$

and also when a liquid is evaporated at constant temperatures the whole of the transfer of heat takes place at this temperature, and the pressure also remains constant, so that

$$\frac{dQ}{d\tau} = Av\frac{dp}{d\tau},$$

but in general

$$\triangle Q = A(\triangle I + \triangle W),$$

I denoting internal energy, and W external work performed, so that

$$\int_{\tau_0}^{\tau_1} v\frac{dp}{d\tau}d\tau = \int_{\tau_0}^{\tau_1} \frac{I+W}{\tau}d\tau.$$

In the case of water I + W has been determined by Regnault experimentally, the result being

$$A(I+W) = 606{\cdot}5 - 0{\cdot}695T - 0{\cdot}00002T^2 - 0{\cdot}000003T^3.$$

To simplify this expression Clausius has proposed writing

$$A(I+W) = 607 - 0{\cdot}708T,$$

which would give

$$A\int_{\tau_0}^{\tau_1} v\frac{dp}{d\tau}d\tau = 607 \log_e \frac{\tau_1}{\tau_0} - {\cdot}708(\tau_1 - \tau_0) + 193{\cdot}3 \log_e \frac{\tau_1}{\tau_0}$$

$$= 800{\cdot}3 \log_e \frac{\tau_1}{\tau_0} - {\cdot}708(\tau_1 - \tau_0).$$

Solving now equation III, for h we find

$$h = \frac{dr}{d\tau} + c - \frac{A(I+W)}{\tau},$$

which, recollecting that $A(I+W) = r$ when τ is constant, we see is identical with (32) so that finally

$$\int_{\tau_0}^{\tau_1} h d\tau = -800{\cdot}3 \log_e \frac{\tau_1}{\tau_0} + 1{\cdot}013(\tau_1 - \tau_0),$$

*Rankine's Steam Engine and other Prime Movers, p. 400, eq. 12.

and when common logarithms are used,

$$\int_{\tau_0}^{\tau_1} hd\tau = -1842{\cdot}8 \log_a \frac{\tau_1}{\tau_0} + 1{\cdot}013(\tau_1 - \tau_0)$$

This quantity $\int_{\tau_0}^{\tau_1} hd\tau$ represents then the quantity of heat which must be transferred, in order that the temperature of a unit of weight of saturative steam may be changed from the temperature τ_0 to τ_1 cent. degrees. It includes not only the heat equivalent of the variation in internal energy, but that of the external work while the saturated state is continually maintained.

For absolute temperatures in Fahrenheit degrees and when foot pounds per pound of steam, instead of calories are involved, the last formula becomes:

$$\int_{\tau_0}^{\tau_1} hd\tau = -2563522 \log_a \frac{\tau_1}{\tau_2} + 783\,(\tau_1 - \tau_0).$$

But the independent variable is, in this formula, absolute temperature, and were the initial and final states determined by observations on pressure, which is nearly always the case in actual practice, the temperatures corresponding to the observed pressures would have to be first obtained, either by means of a table or by substitution in a formula quite as complex as the one just given; after which the operations above indicated would then have to be performed. It has therefore appeared to me desirable to obtain a formula which would allow of the direct computation of $\int hd\tau$ in terms of pressures.

Taking the differential coefficient with reference to τ, of the general thermo-dynamic expression for the internal energy from some standard value U_0, we have in the case of water and steam:

$$\frac{dU}{d\tau} = c + \frac{d}{d\tau}\int_{x=0}^{x=1} \tau^2 \left(\frac{d}{d\tau}\frac{p}{\tau}\frac{dv}{dx} - \frac{d}{dx}\frac{p}{\tau}\frac{dv}{d\tau}\right) dx,$$

in which if we make $x = v$, we obtain, without material error:

$$\frac{dU}{d\tau} = C + \frac{d}{d\tau}\left(\tau^2 \frac{d}{d\tau}\frac{p}{\tau}\right) v = C + \frac{d}{d\tau}\left(\tau v \frac{dp}{d\tau} - pv\right)$$

the expression for the variation of internal energy of the water in the state of saturated vapor.

The corresponding variation of external work is

$$-p \frac{dv}{d\tau} d\tau.$$

The thermal equivalent of these two quantities will moreover constitute the entire transfer of heat involved, so that we may write:

$$\int_{\tau_0}^{\tau_1} \frac{dQ}{d\tau} d\tau = \int_{\tau_0}^{\tau_1} C d\tau + A \int_{\tau_0}^{\tau_1} \frac{d}{d\tau} \tau v \frac{dp}{d\tau} d\tau - A \int_{\tau_0}^{\tau_1} \frac{d}{d\tau} (pv)\, d\tau - A \int_{\tau_1}^{\tau_0} p \frac{dv}{d\tau} d\tau$$

The first two terms of the second member of this equation constitute the total heat of evaporation of the liquid from the temperature τ_0 at τ_1.

The experiments of Fairbairn and Tate* upon saturated steam have shown that for temperatures not greatly exceeding 288° Fahr., the specific volume of saturated steam may be approximately expressed by the equation:

$$v = 25{\cdot}62 + \frac{1257605}{p + 18{\cdot}29}$$

p being expressed in millimeters of mercury. Substituting a, b, and c respectively for the constants involved, we obtain:

$$dv = -\frac{b\,dp}{(p+c)^2}$$

whence

$$\int p\,dv = \int \frac{-b p\, dp}{(p+c)^2} = \frac{bp}{(p+c)} - b \log_e (p+c) + c_1 =$$

$$p\,(v - a) - b \log_e (p + c) + c_1.$$

The corresponding pressures being substituted for the limits of the definite integrals, and writing H_p for the total heats of evaporation in foot pounds at the corresponding pressures, we find finally:

$$\int_{\tau_0}^{\tau_1} h\,d\tau = \int_{p_0}^{p_1} \frac{dQ}{dp} dp = H_{p_0} - H_{p_1} - \left[a\,(p_1 - p_0) - b \log_e \left(\frac{p_0 + c}{p_1 + c} \right) \right]$$

* Proc. Roy. Soc., Vol. 150, 1860, p. 185. Fairbairn, Mills and Mill-work, Vol. i, p. 220.

When we adopt the pound, square foot and Fahrenheit degree, as our units, the values of a, b, and c become the following:

	$a = 0{\cdot}4104.$	$\text{Log } a = \bar{1}{\cdot}6132145$
for hyp. log's	$b = 56098{\cdot}7.$	$\text{Log } b = 4{\cdot}7489528$
for Briggs' log's	$b = 129173.$	$\text{Log } b = 5{\cdot}1111713$
	$c = 50{\cdot}93+$	$\text{Log } c = 1{\cdot}7069869.$

So that for the specific heat of one pound of saturated steam, sometimes called latent heat of expansion, we have the formula in foot pounds:

$$\int_{\tau_0}^{\tau_1} h d\tau = \int_{p_0}^{p_1} \frac{dQ}{dp} dp = H_{p_1} - H_p + 0{\cdot}4104\,(p_0 - p_1) +$$

$$129173 \log\left(\frac{p_0 + 50{\cdot}93}{p_1 + 50{\cdot}93}\right)$$

To facilitate calculation by this formula, I have computed the following table of approximate values of H_p, on the basis of 1 calorie equal to 424 kilogrammeters; whose approximativeness may be taken as about that of the experiments of Fairbairn and Tate, for which they were adapted.

TABLE.

Lbs. per square inch	Lbs. per square foot	H_p	Lbs. per square inch	Lbs. per square foot	H_p
5	720	874425	75	10800	908614
10	1440	881711	80	11520	909658
15	2160	886369	85	12240	910647
20	2880	889882	90	12960	911597
25	3600	892708	95	13680	912505
30	4320	895126	100	14400	913471
35	5040	897248	105	15120	914206
40	5760	899110	110	15840	915013
45	6480	900816	115	16560	915789
50	7200	902356	120	17280	916536
55	7920	903786	125	18000	917261
60	8640	905080	130	18720	917966
65	9360	906349	135	19440	918649
70	10080	907616			

HOBOKEN, N. J., March 7, 1875.

// JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA,
FOR THE
PROMOTION OF THE MECHANIC ARTS.

VOL. LXIX. APRIL, 1875. No. 4.

EDITORIAL.

ITEMS AND NOVELTIES.

The New Method of Electric Illumination.—Dr. Wilde, a member of the Academy of Sciences of St. Petersburg, and Director of the Central Physical Observatory, has recently made a report to the Academy upon the new mode of producing the electric light proposed by M. Ladyguin, of that city. Since the discovery of the voltaic arc in 1821 by Davy, many attempts have been made to utilize it practically for illumination. But in spite of the regulators devised for the purpose, it still remains variable and inconstant; being too intense used at a single point, it is yet incapable of division. Since the improved magneto-electric machines have reduced the cost of the electric light to only one-third that of coal gas, these efforts to utilize it have been redoubled. And, as a result, M. Ladyguin has made an invention which, in a very simple way, resolves both problems, rendering the light steady, and at the same time capable of division. It has long been known that the electric light proper comes from the intensely heated carbons which the current traverses, the resistance of the air between them developing this heat. So the resistance of a platinum wire placed in circuit causes it to be highly heated; but the light thus obtained, though constant, and entirely controllable, is too

feeble for practical use. M. Ladyguin has conceived the idea of replacing the platinum wire in this experiment by a thin rod of gas carbon; and with complete success. Carbon possesses, even at the same temperature, a much greater light-radiating power than platinum; its calorific capacity is less than one-half that of platinum; it is, moreover, a sufficiently good conductor of heat; so that the same quantity of heat elevates the temperature of a small rod of carbon to nearly double that of a wire of platinum the same size. Again, the resistance of the carbon employed is 250 times greater than that of platinum; hence it follows that a rod of carbon may be fifteen times as thick as a wire of platinum the same length, and yet be heated by the same current to the same degree. Finally, the carbon may be heated to the most intense whiteness without the danger of fusion to which platinum is liable. These are some of the advantages of carbon; its only disadvantage is, that heated in air it burns, and so gradually wastes. But M. Ladyguin has happily obviated this difficulty by enclosing the rod of carbon in a glass cylinder containing no oxygen and hermetically sealed. Dr. Wilde asks, in conclusion, that the Academy recognize the fact that M. Ladyguin has resolved the grand problem of dividing and rendering steady the electric light, in the simplest possible manner, and that they award him, in consequence, the Lomonossow prize.

On the Use of Copper Salts for Preserving Wood.—M. Rottier, an industrial engineer and an instructor in the University of Ghent, has recently communicated to the Belgian Academy of Sciences the results of numerous experiments which he has made upon the properties of wood prepared with salts of copper. We translate from the *Revue Industrielle* the following abstract of his paper. His purpose at the outset was to study the causes which result in the entire destruction of even prepared woods in a longer or shorter time, and to ascertain whether by the employment of methods different from those already in use it would not be possible to increase considerably the durability of wood. Very early in the investigation he established the fact that the comparatively short time for which copper sulphate preserves wood is due to the small quantity which enters into combination with the cellulose; this quantity being readily and completely removed in a short time. Shavings thoroughly impregnated with a solution of copper sulphate, then washed in pure water and dried, were buried in rich garden mould and kept moist by fre-

quent drenchings with rain water. In a short time, the quantity of copper sulphate in them was notably diminished, black spots appeared on the surface of the shavings, and they soon became rotten. The copper sulphate may be removed either by the presence of iron, of certain saline solutions, or of carbonic acid.

I. The first of these causes was established long ago. M. Rottier quotes an early experiment of his, made upon shavings prepared with solutions of copper sulphate containing different quantities of ferrous sulphate, which were subsequently buried and the time of preservation noted. The results of this experiment prove: 1st, that ferrous sulphate possesses a certain amount of antiseptic power, but much more feeble than that of copper sulphate. 2d, that woods prepared with solutions of copper sulphate containing at the same time ferrous sulphate, are preserved under ground nearly as long, unless the iron salt is present in considerable proportion. 3d, that there is no reason for preferring, for the pûrpose of preserving wood, a chemically pure copper sulphate to the commercial article. These last results are in contradiction to the theories of many specialists; among others, to those of M. Boucherie, who has lately stated that only pure or nearly pure copper sulphate could be used for the preservation of wood. M. Rottier quotes in support of his opinion the experiments made by Layen upon a very ancient wheel discovered in the copper mines of San Domingo, in Portugal. This wheel was found in a state of perfect preservation, although it had been immersed for fourteen centuries in water charged with copper and iron sulphates. The wood itself contained in notable quantities, basic sulphates of both the metals mentioned.

II. Again, a certain number of salts exercise a deleterious action upon wood impregnated with copper sulphate. If shavings prepared with copper sulphate are plunged, after being washed and dried, in a solution of calcium chloride, or of sodium or potassium carbonate, it will be noticed that after a short time copper appears in the solution, and that it steadily increases in amount while that in the wood becomes lessened. These facts prove that preservation with copper sulphate is not to be advised for woods which are to be employed in maritime construction; since these woods are attacked by borers as soon as a portion of the copper sulphate has been dissolved. In the same way may be explained the destruction of prepared woods employed in engineering, when they are buried in tunnels or in certain soils, espe-

cially in those which are calcareous; the water present being charged with calcareous salts (calcium bicarbonate, etc.) removes the copper from the prepared wood.

III. Precisely in the same manner, solutions of carbonic acid remove from wood the copper with which it has been prepared. To convince one's self of this fact, it is only necessary to treat prepared shavings with carbonic acid water.

In the second part of his investigation, M. Rottier experimented to ascertain whether an increase in the quantity of metal fixed upon the fiber would increase the durability of the wood. Special processes were necessary to test the question, since when wood is immersed in a solution of copper sulphate, the proportion of metal which combines with the fiber is nearly constant and always very small. He found: 1st, that the use of copper acetate enabled him to fix twice as much copper in the wood; 2d, that even this quantity was increased by heating the wood; 3d, that certain organic bodies act toward copper salts precisely as mordants do relative to coloring matters. These when introduced into the fiber become fixed there, and then cause there the absorption of much more considerable quantities of copper. Experiments are described which were made with the two organic substances which have given the most noticeable results, indigo and catechu; and 4th, that the employment of cuprammonium salts enables a very large quantity of copper to be introduced into the wood. In all the experiments, shavings being prepared according to the different processes and their durability noted, it appeared that this durability was in the direct ratio of the amount of copper fixed by the fiber. The following are the author's conclusions: Among all the various methods of preparing wood which I have now considered, there is only one which appears to me susceptible of practical industrial application with advantage. The high price of copper acetate and of indigo necessitates the rejection, undoubtedly, of these substances for this purpose. The heating of wood injected with copper sulphate does not give results of paramount value, and the employment of catechu is possible only in certain cases of not frequent occurrence. The cuprammonium salts on the contrary may be employed in the great majority of cases, and the small increase in the expense resulting from their use in the preservation of wood will be largely compensated by the much greater durability thus given to the fiber.

The Gramme Magneto-Electric Machine.—We find in the London *Engineer*, of April 2d, the following note from Mr. Wilde, the well-known inventor of the magneto-electric machine bearing his name. As a contribution to the history of the Gramme principle of "endless bobbins," the fact stated by Professor Pacinotti is of great importance.

SIR: I wish to direct attention, through *The Engineer*, to a project which has of late been brought prominently into notice. It is now about two years since Gramme's patent magneto-electric machine was brought, by some speculators, from Paris into this country. The novelty of this machine consisted in giving to the armature the form of a closed ring, wrapped round with a series of small coils of insulated wire, in such a manner that when the ring was caused to rotate before the poles of a permanent or an electro-magnet, a continuous and approximately uniform current of electricity was obtained. This form of armature, I would observe, possesses no practical advantage over the well-known forms contrived by Saxton and Siemens, when arranged to produce the direct current from a well-constructed commutator, but it has the disadvantage of requiring a commutator of complicated construction, and of not producing the alternating current now employed for lighthouse illumination. Had M. Gramme limited the exercise of his ingenuity to improving the magneto-electric machine of which he claims to be the inventor, it might have found a respectable place in the laboratory of the physicist as an instrument of research; but he and those associated with him have, for the purpose of bringing the invention into notice, adopted the principle of electro-dynamic accumulation to produce electric light from an electro-magnet, which, as is well known to those familiar with the history of electrical science, forms no part of Gramme's invention. With the view of giving further publicity to the Gramme machine, the promoters of the speculation obtained permission of the Board of Works to exhibit at their own expense, an electric light from the clock-tower of the Houses of Parliament at Westminster, and with this semblance of Governmental patronage, aided by articles in the *Quarterly Journal of Science*, and other publications, "The Electric Power Company (Limited)" was formed to purchase and work the Gramme invention. The nominal capital of this company was £100,000, out of which the promoters were to receive £65,000. As a small amount only of capital of this company was subscribed by the

public—an amount which would appear to have been insufficient to repay the promoters for their venture—a new company has been recently formed, called "Gramme's Magneto-Electric Company (Limited)" with a nominal capital of £250,000. Out of this capital the vendors of the Gramme invention are to receive the modest sum of £145,000, and, to show their confidence in the undertaking, they have considerately agreed to accept £35,000 of this amount in paid-up shares of the company.

I now come to the more important object of my communication. A short time since, Dr. Antonio Pacinotti, of the University of Pisa, was good enough to send me a reprint of his memoir "Sulle Elettro Calamite Trasversali," from the *Nuovo Cimento* of 1864, vol. xix, p. 378, which contains a description of an electro-magnetic machine with an armature in the form of a closed ring, wrapped round with a series of small coils of insulated wire, in the same manner precisely as in the machine of Gramme. The learned Italian Professor states in his memoir that he had one of these machines constructed as early as 1860, for the Cabinet of Technological Physics of the University of Pisa, and that, with either permanent or electro-magnets, it could be used as a magneto-electric machine for producing a continuous current: "Una macchina magneto-elettrica con currente continua," p. 383. The volumes of the *Nuovo Cimento* are to be found in the libraries of the Royal Institution, London, and other learned societies in Europe and America. The memoir is illustrated with an excellent engraving, from which it will be seen that Signor Pacinotti has anticipated most completely the communication of M. Gramme, entitled "Sur une machine magneto-electrique produisant des courants continus," published in the *Comptes Rendus de l'Academie des Sciences*, tome 73, page 1?5, 1871, as well as his English patent of 1870, No. 1668. What renders the Gramme scheme the more remarkable at the present time is the fact that, in the month after the appearance of Gramme's note in the *Comptes Rendus*, Signor Pacinotti sent his reclamation of the invention to the French Academy, where it was admitted, as will be seen by reference to p. 544, and to the index of tome 73, where it is described as "Une machine electro-magnetique construite en 1860 d'après le même principe que la machine de M. Gramme." It is scarcely necessary for me to state that, as Signor Pacinotti's memoir of 1864 is to be found in the public libraries of this and other countries, the knowledge therein communicated belongs

to the commonwealth of learning, and cannot be made the subject of a valid patent. The publication of these facts, to which I have felt it my duty to draw attention, will, doubtless, prove of public advantage. H. WILDE.

Alderley Edge, near Manchester, March 23.

The Centennial Exhibition.—As was anticipated at the date of the last issue of the JOURNAL, the opening of Spring was the signal for greatly increased activity in the building operations at the Centennial grounds.

The contractors are evidently alive to the importance of pushing forward the work as rapidly as possible, and although somewhat retarded by the unusually late spring, have made very satisfactory progress.

Railroad tracks have been laid into the site of Machinery Hall, and an immense amount of material has been delivered. A planing mill has been erected on the spot, and a considerable portion of the frame-work of the north aisle has been erected. Several hundred men are employed on the various portions of this work.

The work on the Art Building has also advanced greatly. On nearly the entire south front, the granite is set to the height of the top of the columns of the portico, say fifty feet: and is progressing with equal rapidity on other portions. The brick-work on the interior walls is stretching up rapidly, and the setting of the iron-work of the base of the dome will be begun in a few days. Two of the four colossal figures for the base of the dome are modeled and are now being cast in a foundry erected on the spot for that purpose.

Work on the Main Exhibition Building is making good progress.

The engineers and architects, Messrs. Pettit and Wilson, have arranged for a comprehensive system of water supply and drainage which is now being executed.

The arrangement of the principal buildings, a plan of which accompanies this, has been slightly modified from the original design and will be found admirably adapted to the wants of the exhibition.

The grounds comprise 230 acres, lying a short distance west of the Schuylkill river, and are of nearly triangular shape, bounded on the south by Elm Avenue from 41st to 52d street; on the west by the drive to George's Hill; on the north by Belmont drive; the eastern boundary cuts off Landsdown drive which will be turned north and

bridges thrown across Landsdown and Belmont valleys, which with a short stretch of new road between them, will complete the circuit of the enclosure.

There will be thirteen entrances representing the original number of states, and after which they may be named, and at each of these will be ticket offices and turn stiles to record the number of visitors.

Belmont Avenue will be closed at its intersection with Elm Avenue and here the administration offices will be located.

The Main Exhibition Building and Machinery Hall stretch along Elm Avenue, one on either side of Belmont Avenue, with a space of 500 feet between them, which will be laid out in walks and handsomely ornamented.

Horticultural Hall is situated on a plateau of about 16 acres, with the deep ravines on the north and south, known respectively as Belmont and Landsdown valleys, and immediately north of this lie the agricultural grounds of 30 acres with its building.

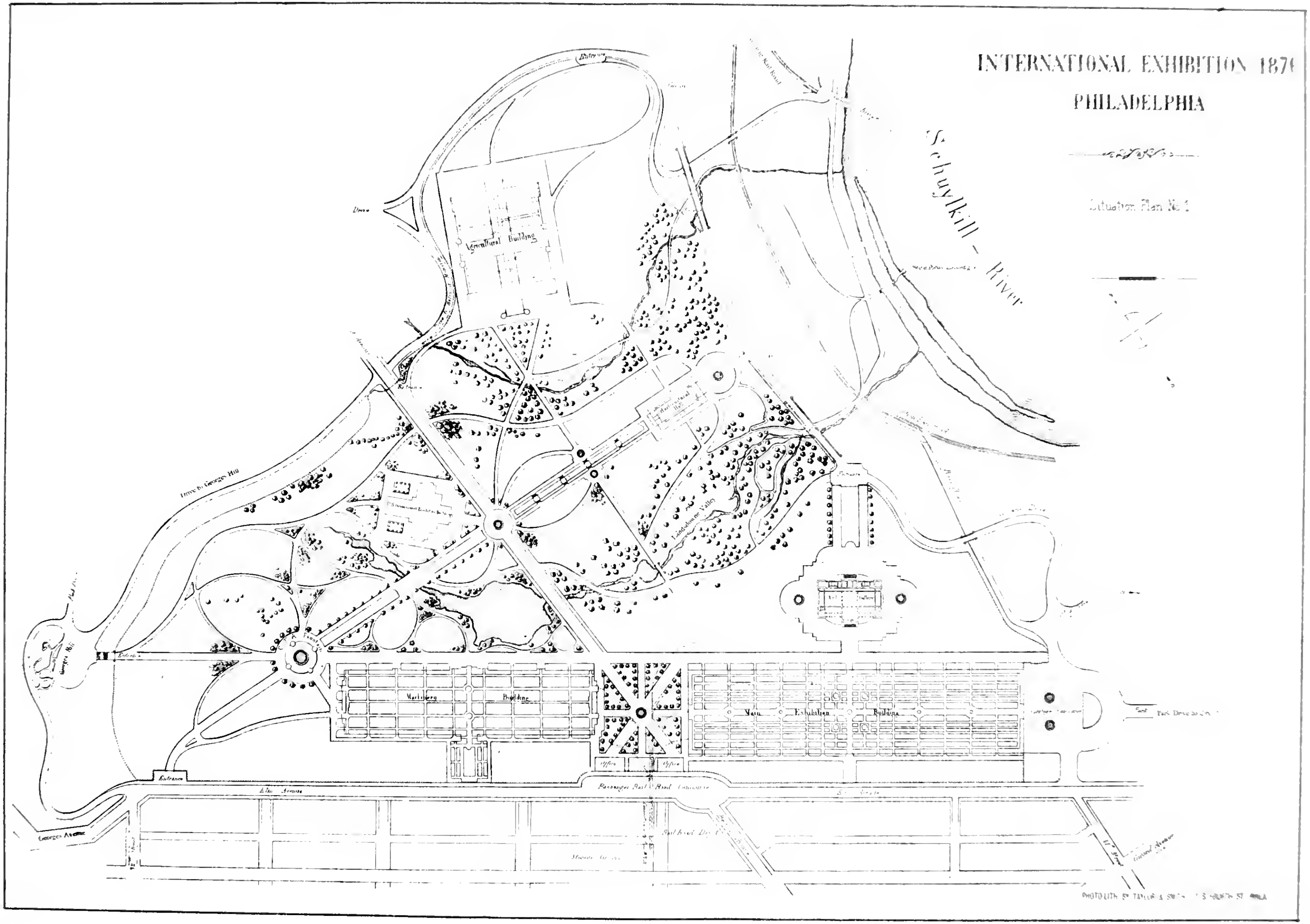
The United States government exhibition building will be near Belmont Avenue, about 800 feet north of Machinery Hall.

This arrangement gives ample space between the principal buildings to locate satisfactorily smaller ones for the use of foreign government commissions and those for special exhibits of which there will no doubt be a large number.

Among the proposed ornamental improvements to the Grounds, are the Terraces around the Art Building and its grand approach from Lansdown drive on the north. The fountain of the Catholic Total Abstinence Society to be placed at the foot of George's Hill, a little northwest of Machinery Hall; the lake in front of the same building; the Terraces and Grand Flower Parterre in the Horticultural Grounds.

The dimensions of the principal buildings are as follows:

Main Exhibition Building, . .	1880 ft.	×	464 ft.	= 20	acres.
Machinery Hall, ...	1402 "	×	360 "	= 12	"
Art Building, ...	365 "	×	210 "	= $1\frac{1}{2}$	"
Horticultural Hall, . . .	350 "	×	160 "	= $1\frac{1}{4}$	"
Agricultural Hall, . . .	820 "	×	540 "	= 10	"
U.S. Government Exhibition Building,	360 "	×	130 "	= $1\frac{1}{2}$	"
Administration Offices, . . .	320 "	×	80 "	= $\frac{3}{4}$	"
Making a Total of . . . . . . - .				47	"


INTERNATIONAL EXHIBITION 187
PHILADELPHIA
Situation Plan No. 1
Schuylkill – River
Agricultural Building
Drive
Drive to Georges Hill
Lansdowne Valley
Machinery Building
Main Exhibition Building
Entrance
Elm Avenue
Passenger Rail Road Concourse
Office
Office
Georges Avenue
Georges Hill

The length of the proposed Horse Railroad within the enclosure for transporting passengers is about 4 miles, and the Freight Railroad tracks for the delivery of goods about $3\frac{1}{2}$ miles, connecting through the Penna., Reading and Junction Railroads with the entire railroad system of the country.

The bridging of the Penna. R. R. at 40th and 41st streets has been so far arranged for that its accomplishment may be considered certain, thus greatly facilitating the approach to the grounds in carriages, especially from the southern and western portions of the city.

K.

The Mills Portable Engine.—The severe test to which the capacity of the Steam Boilers and Portable Steam Engines was subjected at the late Exhibition of the Institute, will make the following statement of the trial of the Portable Engine, known as the "Mills," of interest to engineers and users of this class of machines.

Dear Sir—The results of the test of the "Mills Engine," made by me on the 4th and 5th inst., in the City of New York, is as follows. The engine is what is claimed, of six-horse power, net, of the following general dimensions, arranged on a boiler of the locomotive type:—

Diameter of the cylinder, ...	6·	inches
Stroke of the piston, ...	6·	"
Balance-wheel, or pulley, . . .	6x36·	"
Revolutions for the power named, . . .	200·	
Diameter of boiler—largest part, . . .	19·5	inches
" " smallest part, inside, . .	18·	"
Number of tubes, ...	42·	
Length "	6·	feet
Total water-heating surface, taking outside of tubes,	90·	sq. ft.
Total area of fire-grate, all used, . . .	2·15	"
Diameter of blast-pipe, ...	1·25	inches
" " smoke-pipe above engine, . .	7·	"
Length " " " " . .	8·	feet

Governor of usual description (Waters' patent).

Single slide Davis' patent piston valve, worked by a fixed eccentric.

Boiler jacketed with one-inch felt, and covered with Russia iron.

Weight of engine, boiler, road wheels, etc., a trifle under 3500 lbs.

RESULTS OF THE TEST.

Average steam-pressure carried,	86·3	lbs.
" temperature of feed-water in tank,	42·	degs.
" " " " entering boiler,	210·1	"
" " " smoke (5 in. from tube ends),	421·2	"
" " " steam due to pressure,	321·1	"
Coal weighed out and used,	200·	lbs.
Wood and shavings used,	12·	"
Ash and clinker at end of trial,	53·	"
Water used from tank,	1,312·	"
Total revolutions with full load,	56,268·	
Hours run at actual speed—*mechanical time*,	4·689	
" " " clock time,	4·75	
Indicated horse-power,	7·63	
Water, per indicated horse-power, per hour,	36·2	lbs.
Combustible, per indicated horse-power, per hour,	4·05	"

REMARKS.—To obtain correct evaporative duty of boiler, the water derived from condensation in the heater must be calculated and added to amount drawn from the tank, as the feed-water was heated in a direct contact heater. Owing to the coal being larger than had previously been used, considerably more was put in fire-box during first hour than necessary, causing a loss that could not be calculated, and was not considered. Temperature of feed-water is the average taken by another and myself at different intervals—or one-quarter hour apart.

F. W. BACON,
Mechanical and Consulting Engineer.

Boston, March 10, 1874.

The Rules under which this test was made accompany the Report, over Mr. Bacon's signature, but as they are almost identical with those governing the tests at the Exhibition, and which were published in the JOURNAL for August, 1874, their repetition here is unnecessary. K.

A New Seismometer.—A highly ingenious, though simple, apparatus, designed by M. Malvosia, of Bologna, to indicate the commencement of earthquake shocks, has lately attracted the attention of Italian *savants*. We will try, briefly, to describe it: On a

slightly inclined board is fixed a spherical cap or *calotte* having eight grooves corresponding to the eight principal points of the compass. A little beyond the edge of the cap there is a projecting wooden ring which limits the inclined surface. On the top of the cap is poised a little brass ball, being slightly flattened at the point of contact. Upon the ball rests very lightly a conical weight by a small screw projecting from its base; which weight is suspended by a chain from an overhanging arm movable up and down on a support at the side. It will thus be seen that the least shock will make the ball topple over. When it does so, it runs down one of the grooves of the cap to the inclined plane, at the lower part of which it finds a hole, and passing into it, comes to effect an arrangement by which a gun is fired. But this is not all. Whenever the ball has left its position on the cap, a spring needle, longer than the diameter of the ball, shoots out from the little screw-knob that rested on the ball and catches in that groove of the cap down which the ball has run. Thus the direction is indicated in which the shock has been given; it has been on the opposite side to that in which the needle hangs down. The instrument is said to be very sensitive, and will doubtless render good service in what is now a little understood branch of science.

New Fog Signals.—Professor Tyndall has recently made a series of experiments at Woolwich, England, upon a new signal apparatus for use on the coast during fogs. It consists of a cannon by means of which detonations of variable intensity may be produced. This is effected by the concurrent employment of gunpowder and of gun-cotton.

Bibliographical Notices.

TECHNICAL TRAINING; *being a Suggestive Sketch of a National System of Industrial Instruction, founded on a General Diffusion of Practical Science among the People.* By THOMAS TWINING, one of the Vice-Presidents of the Society of Arts. 8vo., pp. xxiv, 458. London, 1874. (Macmillan & Co.) The subject of Technical Training is one in which just now England is deeply interested. Deaf as she was for a long time to the warnings of some of the most far-

sighted of her scientific men, the Exposition of 1867 opened her eyes to the fact that an era of brains was taking the place of one of simply manipulative skill, and that intelligent, well-trained intellect was a better crop to cultivate than manual dexterity or empirical prestidigitation. Hence have arisen here and there over her domain schools of various grades designed for the mental training of her artisans; so that out of the developed brain should come new ideas of progress which would enable her to maintain her prestige among the nations. But more than this. The subject of education generally, and especially that of the higher education, has received a most valuable impulse from this movement. Broader and more liberal ideas are taking possession of British educators. The masses are to be put to school; they are to be trained in mind as well as in body; to be taught how to grasp and wield an idea as readily as a sledge. Out of this general advance along the line, the book before us comes. Its author has for many years been studying English and Continental Technical Education, and has carefully examined all the plans which have originated, with working men or outside of them, for the improvement of their mental condition. On the very many perplexing questions which arise when the subject of Technical Training is discussed, therefore, he is a most invaluable witness. For example, he cuts at the outset a Gordian knot of no mean proportions when he says: "Train each portion of the community to the full enjoyment of its resources, and to the satisfactory fulfillment of its duties." He believes that there is no danger of too much education anywhere; that the needs of the laboring classes will always impel them rather to too little than to too much study. Hence he would reorganize the apprenticeship system, would provide evening and science and art schools for the working man, and would furnish him with museums where he can see for himself the progress made in branches of labor other than his own. But over and above all this is the grander and wider plan of engrafting technical upon the entire system of national education, so that from his childhood the artisan shall be instructed in those branches of knowledge which he is afterwards to put into practice. In furtherance of this idea, Mr. Twining gives in his book definite plans for systematic instruction, both elementary and advanced; the text books and books of reference necessary in the various parts of the course, the methods of instruction likely to be of most benefit, and finally the examinations which are held at the close. For special purposes, he thinks a central technical university may become necessary, and submits a plan of such a school. Without entering here upon the question how far our system of general education resembles that of England, it is quite clear that in technical education we are in quite as much need of bestirring ourselves as are our English cousins. We too must have schools for training mechanics in science; not only institutions where our young men can afford to spend years in studying a learned profession, be it that of

civil engineer or analytical chemist, but schools where scientific principles, even the most elementary, if need be, can be taught to those who are earning their daily bread by the sweat of their brows during the very time they come for instruction. We commend Mr. Twining's book to all who are interested in this great subject. Especially to those who, having both benevolence of heart and fullness of pocket, are desirous of ameliorating the condition of the working man, as the proximate object, and of placing us in the higher industries, at least by the side of the mother country, as the ultimate object of their benefactions.

MANUAL OF DETERMINATIVE MINERALOGY, *with an introduction on Blowpipe Analysis.* By GEORGE J. BRUSH, Professor of Mineralogy in the Sheffield Scientific School. 8vo., pp. vi. 104. New York, 1875. (John Wiley & Son.)—Professor Brush's eminence as a mineralogist, and his ability and experience as a successful teacher of mineralogy, are well known facts. For this reason we are glad to welcome from his pen the volume before us, which is intended to be one part of the Determinative portion of Dana's Mineralogy. The material in it, he tells us in his preface, was in great part prepared several years ago, and has since been used in his own instruction. It consists of a preliminary portion upon Qualitative Blowpipe Analysis—upon which subject Professor Brush stands as the acknowledged authority in this country—and of a subsequent portion, embracing Determinative Mineralogy proper. This latter portion is based upon the tenth edition of Von Kobell's well-known "Tafeln zur Bestimmung der Mineralien," although much new matter has been added, and the old has been much more conveniently arranged in a set of thirty-three tables, preceded by a complete analysis, by which with the aid of the blowpipe, the mineral under examination may in a few moments, be referred to its proper place. The determinative characteristics as given in the tables are color, streak, cleavage, hardness, specific gravity, fusibility, crystalline form, chemical composition and behavior. From this statement it will be seen that the means which are employed for the determination of mineral species are chiefly pyrognostic, and that after the mineral has been thus fixed, the other physical characters are given to complete the identity. The author expresses his intention to add at some future time other tables for the determination of minerals by their physical characters alone. This will add greatly to the usefulness of the work. We trust also that the crystallographic portion will soon be put into print, since a good English treatise on the system of crystallography adopted by Dana is yet a desideratum. Professor Brush's book is well and carefully printed, and is creditable to the house which has issued it.

Franklin Institute.

Hall of the Franklin Institute, March 17th, 1875.

The stated meeting was called to order at 8 o'clock P. M., the President, Robt. E. Rogers in the chair. There were 129 members present.

The minutes of the stated meeting held February 17th last were read, and after some discussion were adopted as read.

The Actuary presented the minutes of the Board of Managers, and reported that at their stated meeting held the 10th inst., the following donations to the library had been received:

Annual Report of the Secretary of the American Iron and Steel Association, Dec. 31st, 1874. Philada. From the Association.

Statistical Society Almanac for 1875. London. From the Society.

Narrow Gauge Railways in America, also a Directory of Narrow Gauge Railways in North America, by Howard Fleming. From the Authors.

Fifth Annual Report of the Directors of City Trusts, Report for the year 1874. From the Board of City Trust.

The Secretary reported from the Committee on Models that they had met and organized, and had asked the Board of Managers for an appropriation of one hundred dollars, to be expended in putting the Cabinet of Models in order. This appropriation has been made, and is now being expended under the direction of the committee.

The Secretary presented his report, which was principally devoted to lantern illustrations of the Centennial Exhibition grounds and buildings, with descriptions; and some comments on the success of the late exhibition held by the Institute.

He also presented a new castor for furniture, the invention of G. W. Waite, the principal peculiarity of which consists in the weight being sustained by a series of conical rollers standing on end at a small inclination from the perpendicular, between a central spindle and an outer case, enabling the castor to adjust itself to any desired line of motion with a very small amount of friction.

The Secretary also stated that considerable interest had been felt in the matter of magneto-electric machines, from the fact of a Gramme machine having been recently put in operation by Prof. Barker, at the University of Pennsylvania, and hoped that it would be exhibited at the next meeting.

In response to the request of the President, Mr. C. L. Chapin gave some account of the efforts being made to introduce these machines in this country, and stated that he hoped they would soon be put on this market.

Under the head of deferred business the proposed amendments to the by-laws laid over from the last meeting were called up, which are as follows:

Resolved, That Section III, Article 5, of the by-laws, be amended by changing the hours of opening the polls from 4 o'clock to 3 o'clock P. M , and the hour of closing the polls from 8 o'clock to 9 o'clock P. M.

Resolved, That Section I, of Article 5, of the by-laws, be amended by adding to the first sentence the following: "And provided further, that no member shall be eligible for re-election as Manager or Vice-President, for the period of one year after his term of office has expired."

A very wide discussion followed, participated in by Messrs. LeVan, Close, Helm, Hoover, Brown, Purves, Sartain, Trautwine, Eldridge, Tatham, Mitchell, Lipman, Weaver and Heyl. On being put to vote separately, the resolutions were lost.

In reply to a question the Secretary stated that the number of season tickets to the Exhibition issued to members was 1324, to exhibitors 803, to the employees of exhibitors 1167, making a total of 3284 free season tickets, exclusive of press and other complimentary tickets.

Mr. Close asked the chair to make a decision as to the exact construction to be put on the by-law requiring the polls to close at 8 o'clock, and as to whether or not those members who are in line at that hour shall be allowed to deposit their ballots.

Mr. Grimshaw stated that he had embodied that point in a proposed amendment to the by-laws, which he handed the Secretary, as follows: "Amendment offered to Section III, Article 5, to change the hour of opening the polls, from 4 o'clock to 3 o'clock, and to insert the words, all voters who shall be present in the room of election prior to 8 o'clock P. M. shall be entitled to have their votes received."

The President said, I think in fairness to those who come, under circumstances, sometimes, of unavoidable delay, that it would be even-handed justice that all who are in the voting room at the time, and all in line are at liberty and should have the privilege of voting. This is my decision.

Some discussion followed, but no appeal was taken from the decision, whereupon Mr. Grimshaw withdrew his proposed amendment.

Under the head of new business the following extract from the minutes of the Board of Managers was presented:

"The Secretary presented a memorandum showing the attendance in the Library on Sunday, from August 1st, 1874, to February 7th, 1875, between the hours of 12 M. and 4 P. M., was an average of $3\frac{1}{4}$ persons per day, and from 10 A. M. to 4 P. M. there was an average of 5 per day, and many of these were persons who could as well use the library on other days, or in the evenings. The Secretary therefore offered the following, which was adopted:

"*Resolved*, That in view of the small attendance at the library on Sunday, as shown by the memorandum, the Board of Managers recommend to the Institute that its opening on Sunday be discontinued."

Mr. Purves moved, and it was seconded, that in accordance with the recommendation of the Board of Managers, the opening of the library on Sundays be discontinued.

Mr. Chabot moved to amend by postponing action for three months, and in the mean time a record be kept of the attendance during the week and on Sunday; which, on being put to vote, was lost.

The question recurring on Mr. Purves' motion, it was carried.

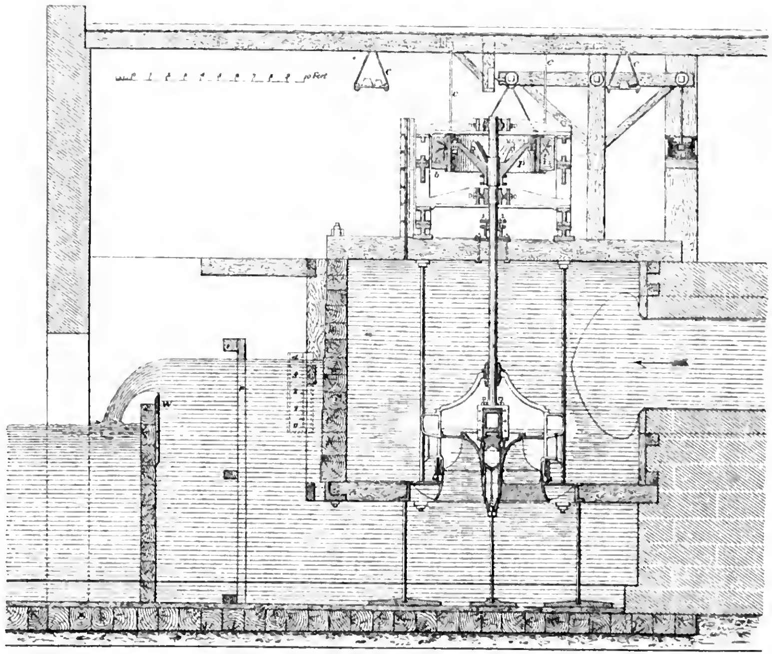
Mr. Chabot wished to have his vote recorded "*No.*"

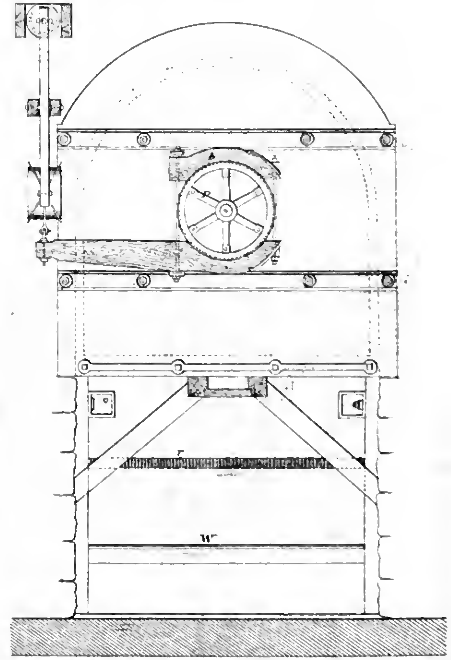
The President urged upon the members the importance of each doing all they can in bringing matters of interest before the monthly meetings, and assured them that they will always meet with the hearty co-operation of the Secretary and other officers of the Institute.

The meteorological section filed a report on the climatic conditions during the months of January and February of this year.

On motion the meeting then adjourned.

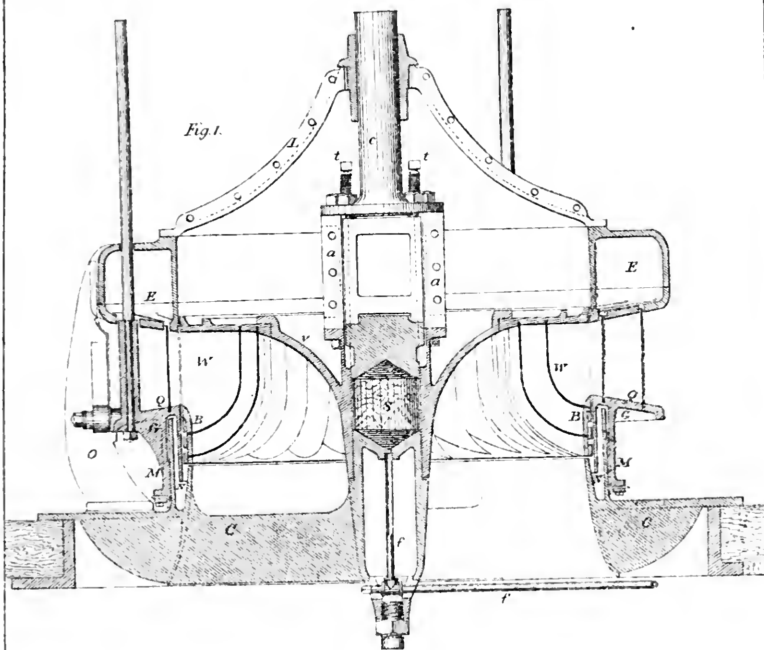
J. B. KNIGHT, *Secretary.*





Lith. Longacre & Co. Phila.

Fig. 1.



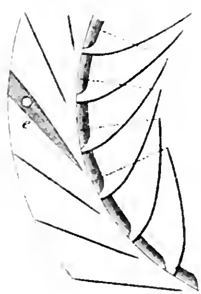


Fig. 2.

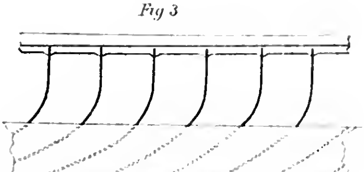
SWAIN TURBINE COMPANY'S

72 INCH WHEEL

0 1 2

SCALE OF FEET

Fig 3



Lith. Longacre & Co Phila

Three ... [illegible] ... Filtrage of the ... [illegible]

The ... [illegible]

During the last ... [illegible] ... or 1849, and it became ... quantity of water ... [illegible] ... required for the purpose ... the wheel, for the purpose ... [illegible]

[* This Paper on the ... [illegible] ... Agent of the Brett Cotton ... [illegible] ... they must therefore be considered ... [illegible]]

Civil and Mechanical Engineering.

REPORT ON A TEST-TRIAL OF A SWAIN TURBINE WATER WHEEL.

By James B. Francis, C. E., of Lowell.*

Dear Sir:—I send you, on the accompanying sheets, the principal data and computed results of the experiments on the Power and Discharge of the Westerly Swain Turbine Water Wheel in your No. 5 Mill.

You are, of course, fully aware of the circumstances under which these experiments were made, but as a matter of record I will briefly describe them.

During the last summer you put in a pair of Swain Turbines, seventy-two inches in diameter, and of about 330 horse-power each, on 18 feet fall; both of the same pattern; in place of the Centre-vent Wheels that had been in use in the same mill since it was built, in 1849; and it became necessary, for the purpose of gauging the quantity of water drawn by the Boott Cotton Mills from the canals of the Proprietors of the Locks and Canals on Merrimack River, to ascertain the quantity of water discharged by them at different heights of speed-gate, and with different speeds. For this purpose a gauging weir was constructed below the Westerly wheel, over which all the water flowed which passed through the wheel. This was all that was required for the purpose of gauging the quantity of water discharged At your request, however, I at the same time weighed the power of the wheel, for the purpose of ascertaining its efficiency as a motor.

[* The Report on the Swain Turbine here given, was made to A. G. Cumnock, Esq., Agent of the Boott Cotton Mills, Lowell, Mass. In the note accompanying the manuscript sent us, the author states that the experiments were made with great care, the necessary apparatus being constructed at considerable cost. He also states that the makers of the Turbine had nothing to do with the experiments, and bore no part of the expense; they must therefore be considered free from any bias in favor of the makers.—Ed.]

The apparatus used for weighing the power was substantially the same as was used in testing the Centre-vent Water Wheel in the same mill, in 1849, a description of which is given in "Lowell Hydraulic Experiments," the second edition of which was published in 1868. The friction pulley and the bell crank were identically the same as used before. The brake was new. The hydraulic regulator was the same as was used in testing the Tremont Turbine in 1851, and is also described in the work above referred to.

The principal difference in the apparatus was in the weir, which in this case was without contraction at the ends. This was so made in order to obtain a greater length of weir; the power, and, of course, the quantity of water discharged, being considerably greater in the Swain wheel than in the Centre-vent wheel it replaces. The formula determined from the experiments made at the Lower Locks, in 1852, for computing the flow over a weir requires complete contraction at the crest, and either complete contraction, or none, at the ends. In this case the contraction at the crest was complete, and at the ends nothing; the discharge has been computed by the formula

$$Q = 3{\cdot}33\ LH^{\frac{3}{2}}$$

In which

Q = the quantity of water discharged, in cubic feet per second.
L = the length of the weir = 16·311 feet.
H = the depth on the weir, in feet.

The discharge from the wheel caused great commotion in the wheel-pit, and the weir being too near to permit the water to free itself, naturally, from disturbance before reaching the weir, a rack or grating in which about one-fifth of the area was open for the passage of the water, was placed parallel to, and about 4·5 feet distant from the weir; the relative position of wheel, rack and weir, being the same as in the experiments on the Centre-vent wheel in 1849, and represented on Plate VIII "Lowell Hydraulic Experiments." The fall in passing the rack (on which its efficiency in equalizing the flow mainly depends), in the experiments with the speed-gate fully open, was about 0·2 feet. The crest of the weir was 12·08 feet above the bottom of the race-way. The depth on the weir was observed by means of a hook-gauge, placed in a tight box on the upper side of the rack, which communicated by means of a lead pipe 0·75 inch in diameter with the space between the rack and the weir; the lower part of the

pipe being placed an inch or two above the floor of the wheel-pit, in the angle formed by the floor and the weir, where there is the least motion in the water; the lower end being closed, and the communication maintained by means of holes in said lower part of the pipe, one-eighth inch diameter, one foot apart. The water had a free fall from the weir, the height of the water on the down-stream side of the weir, being in no experiment less than 2·5 feet below the top of the weir. The fall acting on the wheel was observed by noting the height of the water in the wheel-pit and the head in the penstock, substantially as in the experiments of 1849, above referred to. The box containing the gauge for observing the height in the wheel-pit, communicated with the wheel-pit, by means of a lead pipe 0·75 inch in diameter, placed in the angle formed by the floor and wall of the pit, pierced with holes one-eighth inch diameter, about one foot apart. The brake was of oak, the long arm having an effective length of 10·760 feet, which was increased by the unequal lengths of the arms of the bell-crank to $10{\cdot}760 \times \frac{5{\cdot}000}{4{\cdot}495} = 11{\cdot}969$ feet.

The weight of the brake was . . .	3228·75	pounds.
" " friction pulley, . .	5025·00	"
	8253·75	"

The friction pulley takes the place of a bevel gear weighing 2440 pounds. The difference between the weight of the brake and friction pulley and the bevel gear, viz., 5813·75 pounds, was counterbalanced by a combination of suspension rods, levers and weights, which left the same weight on the step on which the wheel runs, during the experiments, as in the ordinary running of the wheel. The counterbalance relieves the step of the extra weight, by means of the brake lifting against the upper flange of the friction pulley.

The weights used were mostly pieces of pig iron of various weights, which were marked upon them by the City Sealer of Weights and Measures. As a check, the weights in the scale were frequently taken out and weighed in a mass on platform scales. The bell-crank, which formed the scale-beam, was balanced when there was no weight in the scale.

The floor and walls of the wheel-pit were water-tight. The leakage at the weir, if any, was too small to be taken account of.

TABLE 11.

Coefficients of Useful Effect for several heights of Speed Gate, and Velocities of wheel, deduced from the Experiments made on the Seventy-two inch Swain Turbine Water Wheel, in Boott Cotton Mill No. 5, in August, 1874.

Height of opening of Speed Gate, Inches.	Coefficients of Useful Effect; the Ratio of the Velocity of the Exterior Circumference of the wheel to the Velocity due the head acting on the wheel, being as given in the headings of the several columns.																				
	0·60	0·61	0·62	0·63	0·64	0·65	0·66	0·67	0·68	0·69	0·70	0·71	0·72	0·73	0·74	0·75	0·76	0·77	0·78	0·79	0·80
13·08 Full Gate	0·765	0·771	0·776	0·782	0·788	0·793	0·798	0·803	0·808	0·813	0·818	0·822	0·827	0·830	0·832	0·834	0·835	0·835	0·834	0·833	0·831
12·00	0·775	0·781	0·786	0·791	0·793	0·802	0·807	0·811	0·816	0·820	0·824	0·828	0·832	0·835	0·837	0·838	0·830	0·838	0·837	0.835	0·831
11·00	0·775	0.781	0·786	0·792	0·797	0·802	0·807	0·812	0·817	0·821	0·825	0·829	0·831	0·833	0·833	0·832	0·830	0·827	0·824	0·819	0·815
10·00	0·782	0·788	0 794	0·800	0·805	0·810	0·815	0·820	0·824	0·828	0·831	0·833	0·834	0·834	0·833	0·831	0·828	0·824	0·820	0·814	0·809
9 00	0·779	0·785	0 791	0·737	0·803	0·808	0·812	0·816	0·820	0·823	0·825	0·827	0·828	0·827	0·825	0·823	0·820	0·815	0·811	0·806	0·800
8·00	0·771	0·777	0·783	0·788	0·793	0·797	0·800	0·802	0·804	0·805	0·806	0·807	0·806	0·805	0·803	0·800	0·798	0·795	0·791	0·788	0·783
7·00	0·764	0·769	0·774	0·778	0·781	0·784	0·787	0 788	0·790	0·790	0·790	0·790	0·788	0.786	0·783	0·780	0·777	0·772	0·768	0·763	0·757
6·00	0.742	0·747	0·751	0·754	0·757	0·759	0·760	0·761	0·761	0·760	0·759	0 758	0·756	0·753	0·751	0·747	0·743	0·739	0·734	0·728	0·722
5·00	0·708	0·711	0.714	0·717	0·719	0·721	0·722	0·722	0·721	0·720	0·719	0·718	0·717	0·715	0·713	0·710	0·707	0·704	0·701	0·697	0·693
4·00	0·654	0·658	0·661	0·664	0·666	0·668	0·669	0·669	0·668	0·667	0·665	0·663	0·660	0·657	0·655	0·652	0·648	0·645	0·641	0·637	0·633
3·00	0·576	0·579	0·581	0·583	0·585	0·586	0·586	0·586	0· 85	0 584	0·582	0·580	0·578	0·575	0·571	0·568	0·563	0·559	0·555	0·550	0·545
2·00	0·474	0·474	0·473	0·472	0·471	0·469	0·466	0·463	0·460	0·456	0·451	0·446	0·441	0·434	0·428	0·420	0·412	0·404	0·395	0·385	0·375

TABLE I.

Experiments on the Power of, and Quantity of Water discharged by the Westerly Seventy-Two Inch Swain Turbine Water Wheel, in Boott Cotton Mill, No. 5, at Lowell, Mass.

No. of the experim't	Date, 1874	Temperature. Of air in wheel room. Deg. Fahr.	Temperature. Of water in wheel pit. Deg. Fahr.	Height of the Regulating gate. Inches.	Time. Beginning of the experiment. Hours.	Min.	Sec.	Time. Ending of the Experiment. Hours.	Min.	Sec.	Duration of the experim't. Seconds.	Total number of revolutions of the wheel during the experiment.	Weight in the Scale. Pounds Avoir.	Useful effect, or the friction of the brake. Pounds raised one foot per Second.	Total fall acting upon the wheel. Feet.	Depth of water on the weir. Feet.	Quantity of water passing the weir. Cubic feet per Second.	Weight of a Cubic Foot of water. Pounds.	Total power of the water. Pounds raised one foot per Second.	Ratio of the useful effect to the Power expended.	Ratio of the velocity of the exterior circumference of the wheel to the velocity due the fall acting on the wheel.	Quantity of water which passed the wheel, reduced to a uniform fall of 17 feet. Cubic feet per Second.	REMARKS.
1	Aug. 1, A. M.			3·25	9	17	6·5	9	23	47·5	401·0	450	134·56	36673·8	13·963	1·1910	70·865	62·245	61590·6	0·5954	0·7064	78·493	
2	.. ..			..	9	37	2·0	9	46	57·0	595·0	650	159·56	37755·2	13·967	1·1993	71·337	..	62018·9	0·6088	0·6876	78·703	
3	.. ..	75	71·5	..	9	55	55·5	10	7	54·0	718·5	750	184·56	38038·2	13·912	1·2025	71·623	..	62022·1	0·6133	0·6583	79·174	
4	.. ..			..	10	11	48·5	10	21	28·5	580·0	550	234·56	38121·4	13·928	1·2089	72·196	..	62789·8	0·6091	0·5977	79·761	Speed Gate open one quarter, nearly
5	.. ..			..	10	27	27·0	10	34	29·0	422·0	350	284·56	36160·5	13·930	1·2122	72·491	..	62855·3	0·5801	0·5227	80·082	
6	.. ..			..	10	40	9·0	10	46	57·0	408·0	500	385·56	35533·6	13·931	1·1791	69·543	..	60315·8	0·5891	0·7722	76·813	
7	.. ..			6·50	11	10	0·5	11	17	33·5	453·0	600	616·09	64316·3	13·365	1·5823	108·108	..	89935·6	0·7155	0·8522	121·926	
8	.. ..			..	11	20	8·5	11	29	7·0	538·5	650	768·87	69794·0	13·276	1·6157	111·549	..	92180·2	0·7571	0·7792	126·228	
9	.. ..			..	11	31	15·0	11	39	8·5	473·5	550	824·47	72020·4	13·306	1·6296	112·992	..	93853·3	0·7696	0·7490	127·717	
10	.. ..			..	11	41	19·0	11	50	7·0	528·0	600	849·47	72594·4	13·273	1·6340	113·450	..	93729·5	0·7745	0·7337	128·298	
11	Aug. 1, P. M.			..	1	59	27·5	2	8	23·5	536·0	600	874·47	73615·5	13·287	1·6437	114·461	62·240	94671·2	0·7776	0·7224	129·470	
12	.. ..			..	2	9	55·0	2	19	4·5	549·5	600	899·47	73858·8	13·286	1·6185	111·963	..	95079·3	0·7768	0·7046	130·042	Speed Gate open one half, nearly
13	.. ..			..	2	25	17·5	2	34	38·5	561·0	600	924·47	74356·5	13·283	1·6535	115·486	..	95490·1	0·7787	0·6903	130·649	
14	.. ..			..	2	36	13·0	2	47	19·5	666·5	700	949·47	74992·3	13·316	1·6596	116·126	..	96257·8	0·7791	0·6770	131·210	
15	.. ..			..	2	58	57·5	3	6	43·5	466·0	400	1074·47	69359·5	13·249	1·6611	116·599		96163·3	0·7213	0·5547	132·077	
16	.. ..			13·00	3	23	16·0	3	27	45·0	269·0 *	500			13·291	1·6616	116·336	..	96250·8		1·1393	131·572	Brake loose on friction pulley
17	.. ..			..	3	33	41·5	3	41	8·5	627·0	800	1074·47	103029·0	12·685	2·0618	160·803	..	126974·8	0·8120	0·8427	186·140	
18	.. ..			..	3	50	26·0	3	58	54·0	508·0	600	1213·22	107761·8	12·712	2·0862	163·666		129540·5	0·8321	0·7792	189·268	
19	.. ..		73	..	4	1	7·0	4	10	52·0	585·0	650	1290·22	107810·0	12·666	2·0983	165·092		130166·2	0·8282	0·7344	191·263	
20	.. ..				4	13	8·5	4	24	32·0	683·5	750	1315·22	108532·3	12·703	2·1037	165·730		131050·7	0·8282	0·7242	191·722	Speed Gate fully open, nearly
21	.. ..				4	29	19·0	4	36	30·5	431·5	450	1365·22	107071·3	12·716	2·1071	166·167		131531·0	0·8140	0·6879	192·150	
22	.. ..				4	40	9·5	4	49	7·0	537·5	450	1514·47	95352·6	12·579	2·1015	165·470		129767·9	0·7359	0·5553	192·352	
23	Aug. 4, P. M.			2·00	5	12	9·5	5	23	4·5	655·0	950	90·00	9816·6	14·312	0·9143	47·185	62·272	42229·5	0·2320	0·9018	51·753	
24	.. ..			..	5	25	26·5	5	31	58·0	391·5	550	115·00	12149·7	14·309	0·9207	47·985		42750·7	0·2842	0·8736	52·302	
25	.. ..			..	5	32	34·0	5	41	18·5	524·5	700	148·69	14923·6	14·321	0·9297	48·690		43130·6	0·3456	0·8295	53·043	
26	.. ..			..	5	44	32·0	5	51	5·0	393·0	500	173·69	16618·4	14·279	0·9363	49·209	..	43756·0	0·3798	0·7920	53·674	
27	.. ..			..	5	51	46·0	5	57	54·5	368·5	450	198·69	18216·9	14·288	0·9403	49·525	..	44064·5	0·4141	0·7599	54·021	
28	.. ..			..	5	58	57·5	6	5	4·5	387·0	450	223·69	19560·8	14·342	0·9474	50·087	..	44732·9	0·4373	0·7222	54·541	
29	.. ..			..	6	8	21·5	6	20	47·5	744·0	750	284·56	21572·5	14·283	0·9611	51·177		45518·7	0·4739	0·6274	55·833	
30	Aug. 5, A. M.			..	7	38	42·5	7	47	19·0	516·5	500	294·56	21444·3	14·228	0·9616	51·217	62·268	45375·9	0·4726	0·6037	55·985	
31	.. ..			..	7	48	19·5	7	57	30·5	551·0	450	344·56	21162·3	14·190	0·9673	51·678	..	45657·7	0·4635	0·5100	56·559	
32	.. ..		70·5	3·00	8	8	22·5	8	16	33·5	491·0	400	528·72	32392·3	13·979	1·1701	68·748	..	59841·2	0·5413	0·5125	75·8[illegible]	
33	.. ..			..	8	18	17·5	8	26	42·5	505·0	500	464·69	34600·3	13·973	1·1653	68·325	..	59447·8	0·5820	0·6230	75·363	
34	.. ..			..	8	29	7·0	8	37	2·0	475·0	500	439·69	34806·7	13·977	1·1617	68·003	..	59189·5	0·5881	0·6623	75·004	
35	.. ..				8	39	20·0	8	45	24·5	361·5	400	414·69	34223·5	13·972	1·1569	67·588	..	58802·0	0·5820	0·6906	74·553	
36	.. ..			..	8	46	8·5	8	54	8·0	479·5	550	389·69	33611·9	13·960	1·1502	67·002	..	58241·8	0·5772	0·7221	73·9[illegible]	
37	.. ..			..	8	56	56·0	9	[illegible]	53·0	417·0	500	364·69	32884·8	13·988	1·1445	66·504		57925·4	0·5677	0·7541	73·3[illegible]	
38	..				9	5	54·0	9	12	36·0	402·0	500	339·69	31773·5	14·026	1·1377	65·912	..	57565·9	0·5519	0·7812	72·504	
39	.. ..				9	14	28·0	9	2[illegible]	40·0	552·0	750	281·00	28712·2	14·011	1·1196	64·346	..	56137·5	0·5115	0·8538	70·878	
40	..			..	9	25	59·5	9	30	37·5	278·0	400	231·00	24995·7	14·049	1·1051	63·100		55199·8	0·4528	0·9030	69·411	
41	.. ..		70·5	4·00	9	42	35·0	9	48	34·0	359·0	550	231·00	26614·5	13·899	1·2152	72·761		62971·6	0·4226	0·9666	80·469	
42	..			..	9	51	23·5	9	55	57·5	274·0	400	298·81	32805·2	13·853	1·2430	75·272	..	64929·2	0·5052	0·9226	8[illegible]·[illegible]84	
43	..			..	9	57	9·5	10	2	33·5	324·0	450	367·00	38332·9	13·812	1·2646	77·242	..	66431·8	0·5770	0·8791	85·6[illegible]4	
44	.. ..			.	10	[illegible]	51·5	10	10	20·5	389·0	500	443·81	42899·8	13·782	1·2918	79·718		68437·6	0·6268	0·8144	88·570	
45	..			..	10	11	43·0	10	19	18·5	455·5	550	496·94	45124·9	13·764	1·3106	81·495		69845·7	0·6461	0·7656	90·570	
46				.	10	20	1·0	10	27	51·0	470·0	550	521·94	45932·8	13·741	1·3168	82·071	..	70224·3	0·6541	0·7426	91·283	
47				..	10	29	18·5	10	36	41·0	442·5	500	546·94	46476·6	13·703	1·3213	82·495	..	70389·4	0·6603	0·7180	91·885	
48				.	10	37	27·0	10	43	31·5	364·5	400	571·94	47201·0	13·703	1·3272	83·048	..	70861·4	0·6661	0·6973	92·504	
49				.	10	45	9·5	10	52	31·0	441·5	450	621·94	47672·5	13·699	1·3362	[illegible]	.	[illegible]	[illegible]	[illegible]		
50				5·00	11	15	43·0	11	24	10·5	507·5	550	713·31	58135·7	13·440	1·4706	96·865	..	81064·5	0·7172	0·6954	108·941	
51					11	24	59·0	11	30	42·0	343·0	350	771·19	59179·7	13·482	1·4794	97·736	..	82048·8	0·7213	0·6537	109·749	
52				.	11	3[illegible]	21·5	11	40	27·5	426·0	400	828·34	58492·0	13·444	1·4882	98·609	..	82548·7	0·7086	0·6024	110·886	
53	..				11	41	27·5	11	42	29·5	62·0	50	887·03	53796·5	13·436	1·4803	97·825	.	81843·5	0·6573	0·5175	110·037	
54	Aug. 5, P. M.				2	44	11·5	2	50	50·0	398·5	350	862·03	56937·7	13·483	1·4846	98·251	.	82487·9	0·6903	0·5626	110·324	
55	.. .				3	2	7·0	3	9	29·5	442·5	500	680·62	57836·1	13·479	1·4613	95·918	..	80529·8	0·7182	0·7239	107·733	
56	..				3	10	13·0	3	18	18·5	515·5	600	655·62	57386·9	13·542	1·4578	95·603	.	80615·6	0·7119	0·7440	107·116	
57	.. ..			..	3	19	30·5	3	26	30·5	420·0	500	630·62	56158·1	13·546	1·4502	94·856	..	80002·7	0·7056	0·7608	106·264	
58	.. ..			.	3	27	50·5	3	35	9·0	438·5	550	580·62	54767·5	13·552	1·4370	93·561	..	78954·8	0·6937	0·8014	104·793	
59	.			..	3	36	25·0	3	43	16·0	411·0	550	505·62	50881·2	13·589	1·4131	91·240		77203·4	0·6591	0·8539	102·050	
60	.			..	3	41	59·0	3	51	49·0	410·0	600	370·12	40733·1	13·660	1·3671	86·850		73872·7	0·5514	0·9314	96·887	
61	. ..			6·00	4	4	51·0	4	10	21·5	330·5	500	369·56	42045·7	13·539	1·4531	95·141	.	80208·3	0·5242	0·9671	106·610	
62	.			..	4	11	29·5	4	18	22·5	413·0	600	446·37	48767·9	13·518	1·4843	98·222	..	82677·0	0·5899	0·9294	110·148	
63	.				4	19	34·0	4	26	50·0	436·0	600	530·56	55839·6	13·458	1·5167	101·455	.	85019·7	0·6568	0·8824	114·027	
64	.			..	4	28	7·0	4	36	2·0	475·0	600	656·94	62405·3	13·381	1·5513	104·917	..	87442·4	0·7137	0·8123	118·290	
65				.	4	37	25·0	4	44	22·0	417·0	500	720·97	65011·3	13·307	1·5667	106·411	..	88172·4	0·7373	0·7782	120·274	
66				..	4	45	5·0	4	53	1·5	476·5	550	774·09	67193·8	13·355	1·5795	107·821	..	89662·9	0·7494	0·7429	121·648	
67			70·5	.	4	58	46·0	5	2	38·5	532·5	600	799·09	67711·9	13·315	1·5834	108·221	.	89727·7	0·7547	0·7263	122·283	
68				..	5	3	23·0	5	10	11·0	408·0	450	824·09	68351·1	13·314	1·5890	108·795	..	90195·3	0·7578	0·7110	122·936	
69	.				5	10	58·5	5	17	24·5	386·0	400	888·78	69263·5	13·281	1·6016	110·092	.	91044·1	0·7608	0·6689	124·556	
70				.	5	19	5·5	5	26	46·5	461·0	450	945·94	69440·5	13·291	1·6127	111·239	..	92061·1	0·7543	0·6298	125·806	
71					5	47	30·0	5	53	6·0	336·0	300	995·94	66873·3	13·291	1·6089	110·846	..	91736·3	0·7290	0·5761	125·361	
72	A[illegible] A. M.		70·0	7·00	7	37	42·0	7	46	26·0	524·0	800	408·59	46912·0	13·390	1·5379	103·590	62·272	86375·4	0·5431	0·9814	116·722	
73				..	7	47	34·5	7	55	12·5	458·0	650	547·91	58478·3	13·333	1·5889	108·785	..	90321·4	0·6474	0·9142	122·887	
74					7	56	27·5	8	4	10·0	462·5	600	699·91	68281·1	13·199	1·6369	113·752	..	93495·7	0·7303	0·8399	129·096	
75	.			..	8	5	31·5	8	12	25·5	414·0	500	807·16	73310·7	13·164	1·6652	116·711	..	95676·5	0·7662	0·7830	132·634	
76				.	8	13	8·5	8	21	7·5	479·0	550	875·34	75586·1	13·142	1·6817	118·453	..	96939·7	0·7797	0·7450	134·723	
77					8	22	36·0	8	29	59·5	443·5	500	900·34	76384·5	13·126	1·6859	118·897	..	97181·7	0·7855	0·7320	135·310	
78				.	8	31	30·0	8	39	47·5	497·5	550	925·34	76992·3	13·102	1·6894	119·268	..	97309·2	0·7906	0·7184	135·856	
79					8	41	20·5	8	49	58·0	517·5	550	975·34	77965·4	13·114	1·7011	120·541	..	98663·1	0·7901	0·6896	137·087	
80					8	51	37·5	8	59	2·5	445·0	450	1025·34	77975·5	13·088	1·7110	121·563	..	99075·4	0·7870	0·6575	138·541	
81	.				9	0	47·5	9	6	57·5	370·0	350	1075·34	76198·0	13·116	1·7110	121·563	..	99287·4	0·7705	0·6144	138·896	
82				8·00	10	3	5·0	10	[illegible]	[illegible]	[illegible]												

51	.. ..			..	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]													
52	.. ..			..	11	33	21·5	11	40	27·5	426·0	400	828·34	58492·0	13·444	1·4882	98·609	..	82518·7	0·7086	0·6024	110·886	
53	.. ..			..	11	41	27·5	11	42	29·5	62·0	50	887·03	53796·5	13·486	1·4803	97·825	..	81813·5	0·6573	0·5175	110·637	
54	Aug. 5, P. M.			..	2	44	11·5	2	50	50·0	398·5	350	862·03	56937·7	13·483	1·4816	98·251	..	82487·9	0·6903	0·5626	110·324	
55	.. ..			..	3	2	7·0	3	4	29·5	142·5	500	680·62	57836·4	13·479	1·4613	95·918	..	80529·8	0·7182	0·7239	107·753	
56	.. ..			..	3	10	13·0	3	18	48·5	515·5	600	655·62	57386·9	13·542	1·4578	95·603	..	80615·6	0·7119	0·7440	107·116	
57	.. ..			..	3	19	30·5	3	26	30·5	420·0	500	630·62	56458·1	13·546	1·4502	94·856	..	80007·7	0·7056	0·7608	106·264	
58	.. ..			..	3	27	50·5	3	35	9·0	438·5	550	580·62	54767·5	13·552	1·4370	93·561	..	78954·8	0·6937	0·8014	104·793	
59	.. ..			..	3	36	25·0	3	43	16·0	411·0	550	505·62	50884·2	13·589	1·4131	91·249	..	77203·4	0·6591	0·8539	102·050	
60	.. ..			..	3	44	59·0	3	51	49·0	410·0	600	370·12	40733·4	13·660	1·3671	86·850	..	73872·7	0·5514	0·9614	96·887	
61	.. ..			6·00	4	4	51·0	4	10	21·5	330·5	500	369·56	42045·7	13·539	1·4531	95·141	..	80208·3	0·5242	0·9671	106·610	
62	.. ..			..	4	11	29·5	4	18	22·5	413·0	600	446·37	48767·9	13·518	1·4843	98·222	..	82677·0	0·5899	0·9291	110·148	
63	.. ..			..	4	19	34·0	4	26	50·0	436·0	600	539·56	55830·6	13·458	1·5167	101·455	..	85019·7	0·6568	0·8824	114·027	
64	.. ..			..	4	28	7·0	4	36	2·0	475·0	600	656·94	62405·3	13·381	1·5513	104·947	..	87442·4	0·7137	0·8123	118·290	
65	.. ..			..	4	37	25·0	4	44	22·0	417·0	500	720·97	65011·3	13·307	1·5657	106·411	..	88172·4	0·7373	0·7732	120·274	
66	.. ..			..	4	45	5·0	4	53	1·5	476·5	550	774·09	67193·8	13·355	1·5795	107·821	..	89660·9	0·7494	0·7429	121·648	
67	.. ..		70·5	..	4	53	46·0	5	2	38·5	532·5	600	799·09	67711·9	13·315	1·5834	108·221	..	89725·7	0·7547	0·7263	122·284	
68	.. ..			..	5	3	23·0	5	10	11·0	408·0	450	824·09	68351·1	13·311	1·5890	108·795	..	90195·3	0·7578	0·7110	122·936	
69	.. ..			..	5	10	58·5	5	17	24·5	386·0	400	888·78	69263·5	13·281	1·6016	110·092	..	91044·1	0·7608	0·6689	124·556	
70	.. ..			..	5	19	5·5	5	26	46·5	461·0	450	945·94	69440·5	13·294	1·6127	111·239	..	92061·4	0·7543	0·6298	125·806	
71	.. ..			..	5	47	30·0	5	53	6·0	336·0	300	995·94	66873·3	13·294	1·6089	110·846	..	91736·3	0·7290	0·5761	125·361	
72	Aug. 6, A. M.		70·0	7·00	7	37	42·0	7	46	26·0	524·0	800	408·59	46912·0	13·390	1·5379	103·590	62·272	86375·1	0·5431	0·9814	116·722	
73	.. ..			..	7	47	34·5	7	55	12·5	458·0	650	547·91	58478·3	13·333	1·5889	108·785	..	90621·4	0·6471	0·9142	122·837	
74	.. ..			..	7	56	27·5	8	4	10·0	462·5	600	699·91	68284·1	13·199	1·6309	113·752	..	93495·7	0·7305	0·8399	129·096	
75	.. ..			..	8	5	31·5	8	12	25·5	414·0	500	807·16	73310·7	13·164	1·6652	116·714	..	95676·5	0·7662	0·7830	132·634	
76	.. ..			..	8	13	8·5	8	21	7·5	479·0	550	875·34	75586·1	13·142	1·6817	118·453	..	96939·7	0·7797	0·7450	134·723	
77	.. ..			..	8	22	36·0	8	29	59·5	443·5	500	900·34	76334·5	13·126	1·6859	118·897	..	97184·7	0·7855	0·7320	135·310	
78	.. ..			..	8	31	30·0	8	39	47·5	497·5	550	925·34	76952·4	13·102	1·6894	119·268	..	97309·2	0·7906	0·7184	135·856	
79	.. ..			..	8	41	20·5	8	49	58·0	517·5	550	975·34	77955·4	13·144	1·7014	120·541	..	98663·1	0·7901	0·6896	137·087	
80	.. ..			..	8	51	37·5	8	59	2·5	445·0	450	1025·34	77975·5	13·088	1·7110	121·563	..	99075·4	0·7870	0·6575	138·544	
81	.. ..			..	9	0	47·5	9	6	57·5	370·0	350	1075·34	76408·0	13·116	1·7110	121·563	..	99287·4	0·7705	0·6144	138·896	
82	.. ..			8·00	10	3	5·0	10	9	40·5	395·5	600	468·09	53403·8	13·275	1·6288	112·908	..	93337·0	0·5722	0·9794	127·771	
83	.. ..			..	10	10	14·5	10	16	36·5	382·0	550	575·34	62296·2	13·181	1·6649	116·683	..	95774·2	0·6504	0·9328	132·513	
84	.. ..			..	10	18	26·5	10	24	34·0	367·5	500	685·62	70151·0	13·132	1·7026	120·668	..	98677·3	0·7109	0·8831	137·294	
85	.. ..			..	10	25	51·0	10	32	57·5	426·5	550	782·81	75916·8	13·053	1·7298	123·572	..	100443·5	0·7558	0·8396	141·022	
86	.. ..			..	10	34	19·0	10	40	27·0	368·0	450	872·50	80235·7	13·017	1·7536	126·131	..	102240·8	0·7848	0·7972	144·142	
87	.. ..			..	10	42	31·0	10	48	51·5	380·5	450	922·50	82046·9	13·038	1·7635	127·200	..	103274·2	0·7945	0·7704	145·247	
88	.. ..			..	10	50	19·5	10	57	42·0	442·5	500	980·37	83307·6	12·969	1·7750	128·447	..	103734·1	0·8031	0·7380	147·060	
89	.. ..			..	10	59	12·0	11	5	56·5	404·5	450	1005·37	84111·9	12·977	1·7819	129·196	..	104403·9	0·8056	0·7264	147·872	
90	.. ..			..	11	6	42·5	11	14	30·5	468·0	500	1055·37	84794·3	12·968	1·7916	130·253	..	105184·6	0·8061	0·6979	149·133	
91	.. ..			..	11	16	8·0	11	21	55·0	347·0	350	1105·37	83846·3	12·889	1·7939	130·503	..	104745·2	0·8005	0·6609	149·878	
92	.. ..			..	11	22	46·5	11	28	42·5	356·0	350	1133·37	83796·8	12·932	1·7970	130·842	..	105367·2	0·7953	0·6431	150·016	
93	.. ..			..	11	41	43·0	11	47	4·0	321·0	300	1158·37	81414·4	12·894	1·7939	130·503	..	104785·8	0·7770	0·6122	149·849	
94	Aug. 3, A. M.			9·00	8	15	6·5	8	19	46·5	280·0	500	138·75	18633·0	13·438	1·5316	102·954	62·260	86136·4	0·2163	1·1458	115·798	
95	.. ..			..	8	24	15·5	8	28	46·5	271·0	450	290·75	36307·6	13·197	1·6058	110·525	..	90812·6	0·3998	1·0752	125·444	
96	.. ..			..	8	32	28·0	8	37	16·0	288·0	450	437·00	51349·9	13·146	1·6683	117·040	..	95794·1	0·5360	1·0137	133·036	
97	.. ..			..	8	41	46·5	8	46	19·0	272·5	400	586·00	64688·8	13·110	1·7272	123·293	..	100635·3	0·6428	0·9536	140·398	
98	.. ..			..	8	47	32·5	8	54	53·5	441·0	600	735·25	75220·0	12·987	1·7728	128·208	..	103665·0	0·7257	0·8880	146·085	
99	.. ..			..	8	56	11·5	9	3	25·0	433·5	550	874·56	83445·1	12·959	1·8125	132·538	..	106935·6	0·7803	0·8290	151·803	
100	.. ..			..	9	6	57·5	9	14	48·0	470·5	550	1013·31	89080·6	12·872	1·8464	136·274	..	109211·6	0·8157	0·7664	156·608	
101	.. ..			..	9	50	36·5	9	57	18·0	401·5	450	1081·12	91125·2	12·830	1·8614	137·938	..	110181·4	0·8270	0·7360	158·780	
102	.. ..			..	9	59	34·5	10	8	46·0	551·5	600	1106·12	90499·4	12·744	1·8619	137·994	..	109489·9	0·8266	0·7169	159·379	
103	.. ..			..	10	13	27·0	10	22	42·0	555·0	600	1131·12	91961·2	12·836	1·8695	138·839	..	110956·3	0·8288	0·7098	159·780	
104	.. ..			..	10	31	39·5	10	37	13·0	333·5	350	1156·12	91245·8	12·832	1·8714	139·051	..	111090·8	0·8214	0·6891	160·049	
105	.. ..			..	10	38	50·5	10	46	14·0	443·5	450	1181·12	90126·1	12·779	1·8691	138·795	..	110428·1	0·8162	0·6676	160·085	
106	.. ..			..	10	49	37·0	10	56	22·0	405·0	400	1206·12	89584·6	12·804	1·8724	139·163	..	110937·3	0·8075	0·6492	160·352	
107	.. ..			..	11	1	0·5	11	7	40·0	399·5	350	1278·31	84221·9	12·742	1·8714	139·051	..	110511·6	0·7635	0·5773	160·613	
108	.. ..			10·00	11	22	0·0	11	29	19·0	439·0	650	576·31	61171·6	12·914	1·7761	128·566	..	103370·3	0·6208	0·9692	147·509	
109	.. ..			..	11	32	56·5	11	40	39·5	463·0	600	874·56	85231·0	12·810	1·8679	138·661	..	110589·4	0·7707	0·8517	159·737	
110	.. ..			..	11	43	22·5	11	48	24·5	302·0	350	1085·50	94608·2	12·740	1·9230	141·842	..	114887·4	0·8235	0·7638	167·314	
111	Aug. 3, P. M.			..	2	10	57·0	2	18	52·5	475·5	550	1085·50	94123·4	12·742	1·9090	143·263	..	113652·8	0·8308	0·7622	165·478	Repetition of experiment 110.
112	.. ..			..	2	20	22·0	2	27	53·5	451·5	500	1135·50	95566·5	12·681	1·9154	143·984	..	113678·0	0·8319	0·7315	166·710	
113	.. ..			..	2	31	40·0	2	40	13·0	513·0	550	1185·50	95583·9	12·680	1·9224	144·774	..	114292·8	0·8363	0·7082	167·631	
114	.. ..			..	2	45	7·0	2	53	28·0	501·0	500	1235·50	92728·4	12·635	1·9205	144·559	..	113718·3	0·8154	0·6604	167·681	
115	.. ..			..	2	56	3·0	3	4	51·5	528·5	500	1285·50	91460·8	12·704	1·9258	145·158	..	114813·0	0·7966	0·6244	167·917	
116	.. ..			11·00	3	20	14·0	3	24	21·5	247·5	350	735·25	78192·6	12·863	1·8691	138·795	..	111153·9	0·7035	0·9275	159·561	
117	.. ..	71·0	71·5	..	3	28	23·0	3	36	22·0	479·0	550	1136·19	98110·6	12·635	1·9724	150·459	..	118359·1	0·8289	0·7598	174·524	
118	.. ..			..	3	41	54.5	3	50	18·0	503·5	550	1208·37	99266·1	12·640	1·9815	151·501	..	119226·3	0·8326	0·7227	175·698	
119	.. ..			..	3	52	43·5	4	4	6·0	682·5	700	1258·37	97060·2	12·594	1·9819	151·547	..	118828·4	0·8168	0·6798	176·072	
120	.. ..			..	4	5	46·0	4	14	25·0	519·0	500	1308·37	94791·8	12·646	1·9832	151·696	..	119436·4	0·7937	0·6372	175·882	
121	.. ..			..	4	20	55·5	4	29	8·5	493·0	450	1358·37	93244·1	12·598	1·9901	152·488	..	119604·6	0·7796	0·6049	177·138	
122	.. ..			12·00	4	51	54·0	4	57	40·5	346·5	500	725·81	78709·7	12·769	1·9106	143·443	..	114036·9	0·6902	0·9499	165·510	
123	.. ..			..	4	59	2·0	5	7	54·5	532·5	600	1208·87	102435·2	12·521	2·0266	156·703	..	122158·8	0·8385	0·7490	182·592	
124	.. ..			..	5	10	13·5	5	18	47·5	514·0	550	1258·87	101302·1	12·474	2·0324	157·376	..	122223·1	6·8288	0·7126	183·722	
125	.. ..			..	5	23	34·0	5	31	44·5	490·5	500	1308·87	100328·0	12·524	2·0389	158·132	..	123302·2	0·8138	0·6775	184·235	
126	.. ..			..	5	35	12·0	5	40	23·5	311·5	300	1358·87	98419·0	12·537	2·0392	158·166	..	123457·4	0·7972	0·6398	184·180	
127	.. ..			..	5	42	14·0	5	49	38·0	444·0	400	1408·87	95452·2	12·489	2·0417	158·457	..	123211·0	0·7747	0·5996	184·873	
128	Aug. 4, A. M.			13·08	7	47	48·5	7	56	34·5	526·0	950	149·00	20237·7	13·099	1·7000	120·392	62·272	98203·9	0·2061	1·1738	137·152	
129	.. ..			..	8	1	15·5	8	9	57·0	521·5	850	450·25	55189·4	12·880	1·8608	137·871	..	110581·6	0·4991	1·0683	158·395	
130	.. ..			..	8	14	27·0	8	18	26·5	239·5	350	735·25	80804·4	12·603	1·9608	149·133	..	117041·9	0·6904	0·9683	173·206	
131	.. ..			..	8	28	23·0	8	34	9·0	346·0	450	1013·31	99109·8	12·480	2·0453	158·877	..	123471·8	0·8027	0·8660	185·429	
132	.. ..			..	8	35	31·5	8	44	28·0	536·5	650	1136·19	103522·0	12·432	2·0654	161·225	..	124814·5	0·8294	0·8083	188·532	
133	.. ..			..	8	47	20·0	8	56	1·0	521·0	600	1208·37	104652·9	12·372	2·0766	162·538	..	125223·8	0·8357	0·7701	190·528	
134	.. ..			..	9	10	32·5	9	19	20·5	528·0	600	1233·37	105401·9	12·408	2·0854	163·572	..	126387·3	0·8340	0·7588	191·462	
135	.. ..			..	9	50	50·5	9	59	52·0	541·5	600	1258·37	104857·4	12·366	2·0857	163·607	..	125986·6	0·8323	0·7412	191·828	
136	.. ..			..	10	2	8·0	10	21	17·5	1149·5	1250	1283·37	104952·0	12·368	2·0911	164·243	..	126496·7	0·8297	0·7273	192·558	
137	.. ..			..	10	22	53·0	10	33	56·0	663·0	700	1308·37	103885·0	12·385	2·0911	164·243	..	126670·6	0·8201	0·7057	192·426	
138	.. ..			..	10	46	53·5	10	55	31·5	518·0	550	1308·37	104472·3	12·380	2·0957	164·785	..	127037·5	0·8224	0·7098	193·100	
139	.. ..			..	10	57	58·0	11	8	36·0	638·0	650	1333·37	102160·1	12·372	2·0923	164·384	..	126646·6	0·8067	0·6813	192·693	
140	.. ..			..	11	11	9·0	11	20	23·0	554·0	550	1358·37	101116·6	12·386	2·0935	164·526	..	126899·0	0·7992	0·6635	192·749	
141	.. ..			..	11	22	10·0	11	31	57·0	587·0	550	1408·37	99238·3	12·381	2·0940	164·585	..	126893·2	0·7821	0·6264	192·857	
142	.. ..			..	11	33	54·0	11	38	47·0	293·0	250	1481·06	95034·8	12·399	2·0978	165·033	..	127423·8	0·7458	0·5700	193·242	
143	.. ..			..	11	41	11·0	11	48	49·0	458·0	300	1601·56	78892·7	12·399	2·0793	162·855	..	125741·9	0·6274	0·4376	190·692	
144	Aug. 4, P. M.	70	70	..	1	37	51·0	1	50	4·5	733·5	1350			13·173	1·6759	117·841	..	96666·1		1·1928	133·869	Brake loose on friction pulley
145	.. ..			..	1	56	0	2	8	0			1863·62		12·580	1·9840	151·788	..	118907·9	0·	0·	176·450	Wheel prevented from revolving by the brake: the weight in the scale bal'ned the pressure on the buckets.
146	.. ..			..	2	16	0	2	19	0			1863·62		12·556	1·9832	151·696	..	118609·3	0·	0·	176·512	

The experiments detailed on the accompanying sheets, marked Table I, I think require little explanation beyond what is contained in the headings of the several columns. You will observe that they are not in all cases given in the order in which they were made. The first twenty-two experiments were intended to be a preliminary trial, to ascertain if the testing apparatus operated satisfactorily. When they were made it was supposed that the full opening of the speed-gate was 13·00 inches, and they were intended to be made at quarter, half, and full gate. It was subsequently ascertained that the full opening was 13.08 inches. The remaining experiments were made with special reference to determining the quantity of water discharged at each full inch in height of opening of the speed-gate, from two to twelve inches, and when fully open.

The experiments have been plotted on section paper, and a series of curves drawn for the several heights of gate, for the purpose of interpolation and eliminating irregularities.

Table II has been deduced from these curves; it indicates that from 9 inch gate to 13·08 inch gate, or say from about two-thirds gate to full gate, the maximum coefficient of useful effect varies from 0·828 to 0·839, or about one per cent.; the velocity of the exterior circumference of the wheel relatively to the velocity due the head, corresponding to the maximum coefficient of useful effect, being for 9 inch gate about 0·720, and for full gate about 0·765. At half gate the maximum coefficient of useful effect is about 0·78, at a relative velocity of about 0.68. At one-quarter gate, the maximum coefficient of useful effect is about 0·61 at a relative velocity of about 0·66.

Very respectfully,

[Signed] James B. Francis.

Lowell, Mass., Feb. 24, 1875.

APPENDIX.

DESCRIPTION OF THE SEVENTY-TWO INCH SWAIN TURBINE WATER WHEEL BUILT BY THE SWAIN TURBINE CO., LOWELL, MASS., EXPERIMENTED UPON AT THE BOOTT COTTON MILLS, AUGUST 3–7, 1874.

Plate I represents a vertical section through the centre of the wheel and pit, showing the measuring weir w, and the rack r, and also parts of the weighing apparatus, friction pulley p, brake b, and counterbalancing apparatus c c c c.

Plate II represents a plan of the weighing apparatus and measuring flume with weir and rack.

Plate III represents a vertical section through the centre of the wheel, on a larger scale, with a plan of portions of the wheel and gate, and a development of the outer surface of the wheel.

The lower curb C, is a strong disc of cast iron, with a short cylinder upon which the gate moves, and an inner tube with diverging sides, through which the water leaving the wheel is discharged into the pit. There are three arms reaching from the sides of this tube to the hub which forms the pintle upon which the wheel revolves. The step S is a cylinder of white oak, with conical ends, and is free to revolve with the wheel or to remain stationary upon the pintle while the wheel revolves around it. By means of pipe (*f*) water is supplied to the step, passing through its centre and escaping outward over its ends. The intermediate piece a a connecting the shaft c and the wheel coupling v, can be removed to replace the step, without disturbing either the wheel or shaft. The screws t t in the flange of the shaft, are used to adjust the wheel vertically.

The gate G was made with two cylinders, N and M, attached at their tops to a disc Q, which forms an angle of 80° with the cylinders. At the lower end of the outer cylinder is a narrow flange to which is fastened the leather packing, which prevents the escape of water between the gate and the lower curb. This gate has 24 guides, 3 of them being of cast iron, and of the form shown in the plan at e, Plate III. The other guides, 21 in number, are of bronze 0·23 inch in thickness and 18·94 inches long. These are sharpened at each end to 0·04 inch in thickness, with a bevel on each side one inch long; and are so set as to form an angle of 14° with the tangent to the wheel passing through their inner edges.

Outside of, and in a line with, the thick guides, are placed three stands, one of which is seen at o, Fig. 1, Plate III. These support the chamber E, and the wheel cover L. The lower disc of this chamber is slotted, so that the guides may enter the chamber when the gate is raised, by means of the hoisting rods which pass through the thick guides. The plates represent the gate fully opened. The gate is opened by lowering, and closed by raising it, so that when the gate is first opened, the water is admitted into the wheel, immediately under the crown, and the depth of the section of the stream passing through the guides, is increased in proportion as the gate is opened. The lower edge of the chamber, and the upper edge of the gate, are finished so as to form a close joint when brought into contact. The inner edges of the guides are $1\frac{5}{8}$ inches distant, radially, from the outer edges of the buckets.

The wheel W, is 72 inches in diameter at the outer edges of the buckets, and 23·35 inches in depth from the under side of crown to the lower edge of the band. It has 25 buckets of bronze, these being formed between dies in a press, and having the crown plate and the lower band cast upon them of iron.

Fig. 2, Plate III, is a horizontal section just below the crown plate, and represents the form of the bucket for the first six inches below the crown.

Fig. 3 is a development of a portion of the cylindrical surface of the wheel containing the outer edges of the buckets. The discharging edge of the bucket lies in a vertical plane passing through the axis of the wheel, and is parallel to this axis, from the under side of the crown, to a point about $8\frac{1}{2}$ inches below it, and from this point is continued in the form of a quadrant having a radius equal to one-fifth of the diameter of the wheel, and having its centre in the cylinder forming the outer circumference of the wheel. Thus forming, in connection with the surface of the adjoining bucket, an outlet which is in effect a union of two wheels, an inward discharge, and a downward discharge.

The following measurements were made at the mill, before the wheel was started:

Vertical distance from under side of crown to the lower edge of the buckets, ...	23·35	inches.
Vertical distance from the under side of crown to the top of band B, ...	13·285	"
Total area of outlets of wheel (25 in number),	9·558	square feet.
Vertical movement of speed gate, . .	13·08	inches.
Mean shortest distance from the inner edge of one guide to side of adjacent guide (24 in number),	4·532	"
Total area of inlet in speed gate, . .	9·880	square feet.

ON THE MOMENTS AND REACTIONS OF CONTINUOUS GIRDERS.

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(Continued from Vol. lxix, page 215.)

The laws by which the tables of the preceding article may be extended can be stated in algebraic language. The numbers which follow the law for Case I, I shall designate by the letters b_1, b_2, b_r, etc., referring to them in general as the series b. The numbers following the law for the other cases will be represented in the same way by the letters c_2, c_3, c_r, etc. In the discussion of these series it

will be convenient and necessary that the signs of the numbers should be alternately positive and negative, as shown in the following table:

(1)

SERIES b.	SERIES c.*
$0=b_1$	$0=c_1$
$1=b_2$	$1=c_2$
$1=b_3$	$-4=c_3$
$-3=b_4$	$15=c_4$
$-4=b_5$	$-56=c_5$
$11=b_6$	$209=c_6$
$15=b_7$	$-780=c_7$
$-41=b_8$	$2911=c_8$
$-56=b_9$	$-10864=c_9$
$153=b_{10}$	$40545=c_{10}$
$209=b_{11}$	$-151316=c_{11}$
$-571=b_{12}$	$564719=c_{12}$
$-780=b_{13}$	etc.
$2131=b_{14}$	
etc.	

The first of these series which follows numerically the law for Case I is represented by the following equations:

(2)
$$\begin{aligned}
b_2 &= 1\\
b_2 - b_3 &= 0\\
b_2 + 2b_3 + b_4 &= 0\\
-b_3 + b_4 - b_5 &= 0\\
b_4 + 2b_5 + b_6 &= 0\\
-b_5 + b_6 - b_7 &= 0\\
* \quad * \quad * \quad * &\quad * \quad *\\
b_m + 2b_{m+1} + b_{m+2} &= 0\\
-b_{m+1} + b_{m+2} - b_{m+3} &= 0
\end{aligned}$$

where the index m is an *even* number. The second series is represented by the equations:

(3)
$$\begin{aligned}
c_2 &= 1\\
4c_2 + c_3 &= 0\\
c_2 + 4c_3 + c_4 &= 0\\
c_3 + 4c_4 + c_5 &= 0\\
* \quad * \quad * &\quad * \quad *\\
c_r + 4c_{r+1} + c_{r+2} &= 0
\end{aligned}$$

* The numbers composing this series are usually called the Clapeyronian numbers, because first used by Clapeyron, the inventor of the theorem of three moments. (See *Comptes Rendus*, 1857, Vol. xlv, p. 1076.)

In the first of these series, if we eliminate all the numbers with even indices, we have:

$$\begin{aligned} b_3 &= 1 \\ 4b_3 + b_5 &= 0 \\ b_3 + 4b_5 + b_7 &= 0 \\ * \quad * \quad * \quad * & \quad * \quad * \quad * \\ b_{m-1} + 4b_{m+1} + b_{m+3} &= 0 \end{aligned}$$

Hence the numbers with an odd index in the series b are the same as those of the series c.

Eliminating all the numbers with an odd index we have:

(4)
$$\begin{aligned} b_2 &= 1 \\ 3b_2 + b_4 &= 0 \\ b_2 + 4b_4 + b_6 &= 0 \\ b_4 + 4b_6 + b_8 &= 0 \\ * \quad * \quad * & \quad * \quad * \\ b_m + 4b_{m+2} + b_{m+4} &= 0 \end{aligned}$$

Hence all even b's, except b_4, follow the same law as the series c.

If we subtract the alternate numbers composing the series b, a new series may be formed, which will be designated by the letter d, thus:

(5)
$$\begin{aligned} b_3 - b_1 &= d_2 \\ b_4 - b_2 &= d_3 \\ b_5 - b_3 &= d_5 \\ * \quad * & \quad * \quad * \\ b_{r+1} - b_{r-1} &= d_r \end{aligned}$$

From which we may deduce the equations for d,

(6)
$$\begin{aligned} d_2 &= 1 \\ 4d_2 + d_3 &= 0 \\ -d_2 + d_3 - d_4 &= 0 \\ d_3 + 2d_4 + d_5 &= 0 \\ * \quad * \quad * & \quad * \quad * \quad * \\ -d_m + d_{m+1} - d_{m+2} &= 0 \\ d_{m+1} + 2d_{m+2} + d_{m+3} &= 0 \end{aligned}$$

Multiplying together (2) and (6), equation by equation, and reducing, we have:

$$
(7)\qquad
\begin{aligned}
b_2d_2 &= 1\\
4b_2d_2+b_3d_3 &= 0\\
b_2d_2+4b_3d_3+b_4d_4 &= 0\\
b_3d_3+4b_4d_4+b_5d_5 &= 0\\
* \quad * \quad * \quad * \quad * & \quad *\\
b_rd_r+4b_{r+1}d_{r+1}+b_{r+2}d_{r+2} &= 0
\end{aligned}
$$

Therefore $b_2d_2 = c_2$, $b_3d_3 = c_3$, $b_rd_r = c_r$; or generally

$$(8)\qquad b_r(b_{r+1}-b_{r-1}) = c_r$$

Designating by Σc_r the sum of the series c as far as and including c_r we have $\Sigma c_r - \Sigma c_{r-1} = c_r = b_rb_{r+1} - b_rb_{r-1}$, and since this is true for all values of r, we have the important relation:

$$(9)\qquad \Sigma c_r = b_rb_{r+1}$$

Further it is evident that if all the numbers of the series c be multiplied by the same number, the resultant series will follow the same law. Also, if there be two series, each following the same law as c, the sums of the corresponding numbers will be similar series. The same of course holds true for b.*

---

* Many other interesting properties of these series might be deduced, but the above are all that are absolutely required for the purposes of the present paper. A few of the most important are here noted as matters of general interest.

By the addition of equations (3) we get the sum of the first r Clapeyronian numbers,

$$\Sigma c_r = \tfrac{1}{6}(c_r - c_{r+1}+1).$$

The ratios $\frac{c_2}{c_3}, \frac{c_3}{c_4}, \frac{c_4}{c_5}, \ \ldots \ \frac{c_r}{c_{r+1}}$, are comprised within very narrow limits; $\frac{c_2}{c_3} = 0{\cdot}25$, and when r is infinite, $\frac{c_r}{c_{r+1}} = 0{\cdot}26795$. The following formula gives c_n in terms of c_{n-1}:

$$c_n = 2c_{n-1}+\sqrt{3c^2_{n-1}+1}; \text{ or approximately } c_n = 3{\cdot}732c_{n-1}.$$

The relation $c_rc_n - c_{r-1}c_{n-1} = c_{n+r-2}$ is useful in the reduction of complex expressions. The ratios $\frac{c_2}{b_5-b_3}, \frac{c_3}{b_7-b_5}, \ \ldots \ \frac{c_r}{b_{2r+1}-b_{2r-1}}$, which give the inflection points in the unloaded spans, are included between the narrow limits 0·2 and 0·21133. The sum of the first m numbers in the series b is

$$\Sigma b_m = \tfrac{1}{2}(b_m+1);$$

and the sum of the first $m+1$ numbers is

$$\Sigma b_{m+1} = -\tfrac{1}{2}(b_{m+2}-1);$$

m being an *even* number.

The Theorem of Three Moments for continuous girders whose supports are on the same level is for concentrated loads,

$$(10)\qquad M_{r-1}l_{r-1}+2M_r(l_{r-1}+l_r)+M_{r+1}l_r=\frac{P_r}{l_r}(2l^2_r a-3l_r a^2+a^3)$$
$$+\frac{P_{r-1}}{l_{r-1}}(l^2_{r-1}a-a^3)$$

and the reaction at the rth support is:

$$(11)\quad R_r=\frac{M_r-M_{r-1}}{l_{r-1}}+\frac{M_r-M_{r+1}}{l_r}+\frac{P_r}{l_r}(l_r-a)+\frac{P_{r-1}}{l_{r-1}}a\,;$$

where a is the distance of each load from the nearest left hand support.*

When all the spans are equal we have from (10) and (11),

$$(12)\qquad M_{r-1}+4M_r+M_{r+1}=Q+Q'.$$

$$(13)\qquad R_r=\frac{1}{l}(2M_r-M_{r-1}-M_{r+1})+q+q'\,;$$

where Q, q, etc., denote the terms involving P. When the load is uniform, $P=wda$, and the corresponding values of these functions are easily obtained by integration between the limits $a=0$ and $a=l$.

Putting $\frac{a}{l}=k$, we have the following values:

For a uniform load,

$$(14)\qquad Q=Q'=\tfrac{1}{4}wl^2;\quad q=q'=\tfrac{1}{2}wl.$$

For a concentrated load,

$$(15)\qquad Q=Pl\,(2k-3k^2+k^3);\quad Q'=Pl\,(k-k^2).$$
$$q=P\,(1-k);\quad q'=Pk.$$

Formula (12) can be applied to all the supports except the two abutments where the moments are zero. Hence if there be s spans we have $s-1$ equations for the determination of the $s-1$ unknown moments. The reactions can then be found by writing $s+1$ equations of the form of (13), and introducing the values of the moments.

---

* For the demonstration of these important theorems, see *La Mécanique Appliquée*, Vol. III, by Bresse, or *Theorie der continuirlichen Träger*, by Weyrauch.

Thus, if there be six spans all uniformly loaded, the equations of moments are

$$
(16)\qquad
\begin{aligned}
4M_2+M_3&=2Q\\
M_2+4M_3+M_4&=2Q\\
M_3+4M_4+M_5&=2Q\\
M_4+4M_5+M_6&=2Q\\
M_5+4M_6\qquad&=2Q
\end{aligned}
$$

and by ordinary algebraic methods the values of M_2, M_3, etc., may be found. When the number of equations is large, however, the algebraic processes become long and tedious, and it is here that the method of *indeterminate multipliers* becomes particularly applicable. By way of illustration I shall apply the method to the above equations. Let the first equation be multiplied by the indeterminate number c_2, the second by c_3, the third by c_4, etc., and then let all the equations be added together, we have

$$
\begin{aligned}
M_2(4c_2+c_3)+M_3(c_2+4c_3+c_4)+M_4(c_3+4c_4+c_5)+M_5(c_4+4c_5+c_6)\\
+M_6(c_5+4c_6)=2Q(c_2+c_3+c_4+c_5+c_6).
\end{aligned}
$$

Now, in order to obtain M_6, we have only to require such relations to exist between the indeterminate multipliers that all the other terms in the left hand member of the equation shall become zero. This gives us the equations of the multiplier.

$$
(17)\qquad
\begin{aligned}
4c_2+c_3&=0\\
c_2+4c_3+c_4&=0\\
c_3+4c_4+c_5&=0\\
c_4+4c_5+c_6&=0
\end{aligned}
$$

and the values of c_2, c_3, etc., will at once determine M_6.

$$
(18)\qquad M_6=2Q\frac{c_2+c_3+c_4+c_5+c_6}{c_5+4c_6}.
$$

The values of c may be perfectly arbitrary, provided only that they satisfy the above equations. Following the practice of Clapeyron, it is usual to take c_2 as unity, hence we have from equations (17)

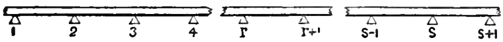
$$
c_2=1.\quad c_3=-4.\quad c_4=15.\quad c_5=-56.\quad c_6=209.
$$

Substituting these values in (18) we have

$$
M_6=2Q\frac{165}{780}=\frac{11}{104}wl^2.
$$

The other moments are now easily obtained direct from (16), thus

$$M_5 = 2Q - 4M_6 = \frac{8}{104} wl^2, \text{ etc.}$$



Let us now apply this method to a girder of s equal spans uniformly loaded; the equations of moments are

$$
\begin{array}{lr}
& 4M_2 + M_3 = 2Q \\
& M_2 + 4M_3 + M_4 = 2Q \\
& M_3 + 4M_4 + M_5 = 2Q \\
& * \quad * \quad * \quad * \\
(19) & M_{r-1} + 4M_r + M_{r+1} = 2Q \\
& * \quad * \quad * \quad * \\
& M_{s-2} + 4M_{s-1} + M_{s+1} = 2Q \\
& M_{s-1} + 4M_s \qquad = 2Q
\end{array}
$$

And the corresponding multipliers are

$$c_2, c_3, c_4, \quad * \quad * \quad * \quad * \quad c_r, \quad * \quad * \quad * \quad * \quad c_{s-1}, c_s.$$

Hence we have at once

$$M_s = 2Q \frac{c_2 + c_3 + c_4 + \ldots . c_r + \ldots . c_{s-1} + c_s}{c_{s-1} + 4c_s}.$$

The numerator in the second member may be designated as Σc_s, and the denominator is equal to $-c_{s+1}$, since $c_{s-1} + 4c_s + c_{s+1} = 0$. Hence

$$M_s = -2Q \frac{\Sigma c_s}{c_{s+1}};$$

but from (8) and (9) we have $c_{s+1} = b_{s+1}(b_{s+2} - b_s)$ and $\Sigma c_s = b_s b_{s+1}$, therefore

$$M_s = -2Q \frac{b_s}{b_{s+2} - b_s}.$$

Since the girder is symmetrical with respect to its centre, we must also have

(20) $$M_2 = M_s = -2Q \frac{b_s}{b_{s+2} - b_s},$$

a result which might be found by changing the order of the multiplier, that is, multiplying the first equation by c_s, the second by c_{s-1}, the rth by c_{s-r+2}, the $s-1$th by c_3, etc., and deducing M_2 by exactly the same processes as given for M_s.

From (19) we find the other moments in terms of M_2,

$$\begin{aligned} M_3 &= 2Q - 4M_2 \\ M_4 &= -6Q + 15M_2 \\ M_5 &= 24Q - 56M_2 \end{aligned}$$

or universally,

$$M_r = 2Q\Sigma c_{r-1} + c_r M_2.$$

Substituting the values $\Sigma c_{r-1} = b_{r-1}b_r$ and $c_r = b_r(b_{r+1} - b_{r-1})$ from (8) and (9), we have after reduction,

$$M_r = 2Q\, b_r \frac{b_{r-1}b_{s+2} - b_{r+1}b_s}{b_{s+2} - b_s}. \tag{21}$$

If there be $s+1$ spans we find in exactly the same way,

$$M_r = 2Q\, b_r \frac{b_{r-1}b_{s+3} - b_{r+1}b_{s+1}}{b_{s+3} - b_{s+1}}.$$

Therefore the numerators and denominators of the coefficients of Q *follow the law of the series b*, and since b_{s+2} and b_s have different signs, as do also b_{r-1} and b_{r+1}, the sign of the fractional part of this coefficient will be the same as the sign of b_r. The moment M_r will then always be positive. Hence the moments follow the law as given for Table A.

A similar proof may be made out for the reactions in *Case I.* From (21) we have M_r, M_{r-1}, and M_{r+1}; substituting these in (13), and putting $q' = q$, we have, after reductions by equations (8) and (9),

$$R_r = q\frac{6b_r(b_{r-1}b_{s+2} - b_{r+1}b_s) + b_{s+2} - b_s}{b_{s+2} - b_s}. \tag{22}$$

Hence the reactions also follow the law of the series b, and since this expression can be placed under the form,

$$R_r = 6\frac{M_r}{l} + q, \tag{23}$$

we see that the reactions are always positive. This expression, however, fails for the abutments, since it is deduced under the supposition

that the load exists on both sides of the support. For the abutments we have from (13), by placing $r=1$ and $r=s+1$,

$$R_1=-\frac{M_2}{l}+q, \text{ and } R_{s+1}=-\frac{M_s}{l}+q.$$

and reducing by the substitution of M_2 and M_s from (18), remembering that $2Q=ql$, we have

$$(24)\qquad R_1=R_{s+1}=q\frac{b_{s+2}}{b_{s+2}-b_s},$$

an expression which must be always positive, since b_{s+2} is greater than b_s.

For *Cases II* and *III* I shall suppose the load to be in the rth span of the girder. The equations of moments will be,

$$(25)\qquad \begin{array}{llr}
c_2 & 4M_2+M_3=0 & c_s \\
c_3 & M_2+4M_3+M_4=0 & c_{s-1} \\
c_4 & M_3+4M_4+M_5=0 & c_{s-2} \\
 & * \quad * \quad * \quad * \quad * & \\
c_r & M_{r-1}+4M_r+M_{r+1}=Q & c_{s-r+2} \\
c_{r+1} & M_r+4M_{r+1}+M_{r+2}=Q' & c_{s-r+1} \\
 & * \quad * \quad * \quad * \quad * & \\
c_{s-1} & M_{s-2}+4M_{s-1}+M_s=0 & c_3 \\
c_s & M_{s-1}+4M_s=0 & c_2
\end{array}$$

where the series c, which is written on the left, gives the multipliers for determining M_s, while those on the right serve to find M_2. Q and Q′ representing in general two different functions of the load, we have

$$M_2=-\frac{Qc_{s-r+2}+Q'c_{s-r+1}}{c_{s+1}},$$

$$(26)\qquad M_s=-\frac{Qc_r+Q'c_{r+1}}{c_{s+1}}.$$

From (25) we have

$$M_3=-\ 4M_2$$
$$M_4=\ 15M_2, \text{ etc.}$$

Or universally, if m be less than or equal to r,

(27) $$M_m = c_m M_2 = -c_m \frac{Qc_{s-r+2}+Q'c_{s-r+1}}{c_{s+1}},$$

and if m be equal to or greater than $r+1$,

(27) $$M_m = -c_{s-m+2}\frac{Q\,'_{r}+Q'c_{r+1}}{c_{s+1}}.$$

Hence we see that the moments follow the law of Clapeyron's numbers.

For the abutment reactions we have from (13)

(28) $$\text{when } r=1,\ R_1 = -\frac{M_2}{l}+q;\ \text{when } r=s,\ R_{s+1} = -\frac{M_s}{l}+q;$$

$$\text{when } r>1,\ R_1 = -\frac{M_2}{l};\ \text{when } r<s,\ R_{s+1} = -\frac{M_s}{l}.$$

For the other reactions, except those at the supports adjacent to the loaded span, we have from (13)

(29) $$R_m = \frac{1}{l}(2M_m - M_{m-1} - M_{m+1}),\ \text{or from (27)}$$

$$R_m = \frac{M_2}{l}(2c_m - c_{m-1} - c_{m+1});$$

but from (3) we have $-c_{m-1}-c_{m+1}=4c_m$; hence

(30) $$R_m = 6c_m\frac{M_2}{l} = 6\,\frac{M_m}{l}.$$

For the reactions at the supports adjacent to the loaded span (when they are not abutment reactions) we substitute (27) in (13) and obtain after reduction,

(31) $$R_r = 6\frac{M_r}{l} - \frac{Q}{l}+q,$$

$$R_{r+1} = 6\frac{M_{r+1}}{l} - \frac{Q'}{l}+q'.$$

Therefore the reactions likewise follow the same law.

It will be noticed that all the tables given in the first part of this article are here presented in terms of a few constants, and the two series, b and c. Formulæ (21), (23), and (24) give the moments and reactions for the case when the whole girder is uniformly loaded, and (27) to (31) for the case when a single span only is loaded, while

the constants are given by (14) and (15). The formulæ are simple and not difficult of application, and may perhaps by some be preferred to the tables. The tables, however, present the quantities more clearly to the eye, and can be readily used by those unfamiliar with the reduction of algebraic expressions.

When the end spans are of different lengths from the others, the above method is also with slight modifications applicable. Suppose such a girder to be loaded in the rth span, and let the lengths of the first and last span be designated by nl, the second and last but one by pl, the others as before by l. Referring to (10) and (11) the functions of the load now become:

(32) For a uniform load.

$$\left\{\begin{array}{l} \text{when } r=1 \text{ or } r=s;\ Q=Q'=\frac{1}{4}wn^3l^2. \\ \qquad q=q'=\frac{1}{2}wnl. \\ \text{when } r=2 \text{ or } r=s-1;\ Q=Q'=\frac{1}{4}wp^3l^2. \\ \qquad q=q'=\frac{1}{2}wpl. \\ \text{when } r>2 \text{ or } r<s-1;\ Q=Q'=\frac{1}{4}wl^2. \\ \qquad q=q'=\frac{1}{2}wl. \end{array}\right.$$

(33) For a single concentrated load.

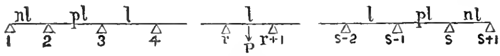
$$\left\{\begin{array}{l} \text{when } r=1 \text{ or } r=s;\ Q=Pn^2l\,(2k-3k^2 \\ \quad +k^3).\quad Q'=Pn^2l\,(k-k^3). \\ \quad q=P\,(1-k).\quad q'=Pk.\quad k=\dfrac{a}{nl}. \\ \text{when } r=2 \text{ or } r=s-1;\ Q=Pp^2l\,(2k- \\ \quad 3k^2+k_3).\quad Q'=Pp^2l\,(k-k^3). \\ \quad q=P\,(1-k).\quad q'=Pk.\quad k=\dfrac{a}{pl}. \\ \text{when } r>2 \text{ or } r<s-1;\ Q=Pl\,(2k- \\ \quad 3k^2+k^3).\ Q'=Pl\,(k-k^3). \\ \quad q=P(1-k).\quad q'=Pk.\quad k=\dfrac{a}{l}. \end{array}\right.$$

and the equations of moments are:

$$\begin{aligned} 2M_2\,(p+n)+M_3p&=0 \\ M_2p+2M_3(p+1)+M_4&=0 \\ M_3+4M_4+M_5&=0 \end{aligned}$$

* * * *

$$
(33)\qquad
\begin{aligned}
M_{r-1}+4M_r+M_{r+1} &= Q\\
M_r+4M_{r+1}+M_{r+2} &= Q'\\
* \quad * \quad * \quad & *\\
M_{s-2}+2M_{s-1}(1+p)+M_s p &= 0\\
M_{s-1}p+2M_s(p+n) &= 0
\end{aligned}
$$



Multiplying these by the indeterminate quantities c_2, c_3, c_r, etc., we get at once the values of M_2 and M_s:

$$
(34)\qquad
\begin{aligned}
M_2 &= \frac{Qc_{s-r+2}+Q'c_{s-r+1}}{pc_{s-1}+2(p+n)c_s}\\
M_s &= \frac{Qc_r+Q'c_{r+1}}{pc_{s-1}+2(p+n)c_s}.
\end{aligned}
$$

And the equations of condition for the multipliers will be:

$$
(35)\qquad
\begin{aligned}
2(p+n)c_2+pc_3 &= 0\\
pc_2+2(p+1)c_3+c_4 &= 0\\
c_3+4c_4+c_5 &= 0\\
* \quad * \quad * \quad & *\\
c_r+4c_{r+1}+c_{r+2} &= 0
\end{aligned}
$$

As before it will be most convenient to assume $c_2=1$; then from (35) we have:

$$
(36)\qquad
\begin{aligned}
c_1 &= 0\\
c_2 &= 1\\
c_3 &= \frac{-2p-2n}{p}\\
c_4 &= \frac{p(4+3p)+n(4+4p)}{p}\\
c_5 &= \frac{-p(14+12p)-n(14+16p)}{p}\\
c_6 &= \frac{p(52+45p)+n(52+60p)}{p}
\end{aligned}
$$

etc., etc.,

by which the values of M_2 and M_s may be found for any number of spans, the load being in any assigned span r.

Since equations (33) and (35) are of the same form,

$$M_3 = c_3 M_2, \ M_4 = c_4 M_2,$$

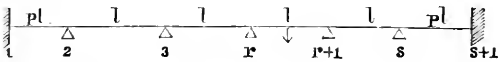
or universally,

$$(37) \qquad \text{when } m < r+1; \qquad M_m = c_m \frac{Qc_{s-r+2} + Q'c_{s-r+1}}{pc_{s-1} + 2(p+n)c_s},$$

$$\text{when } m > r; \qquad M_m = c_{s-m+2} \frac{Qc_r + Q'c_{r+1}}{pc_{s-1} + 2(p+n)c_s}.$$

The laws for the reactions are the same as those for equal spans when $m > 3$, or $m < s - 1$. For other values of m they are best found by the general formula (11), by placing q and q' for the terms containing P, remembering that q corresponds to a load on the span following the support considered, and q' to a load on the span preceding.

If in the foregoing expressions we make $n = 0$, the points 1 and 2 fall together, and the reactions at those points become infinite and opposed. This is the mathematical condition for fastened ends, that is, ends where the tangent to the elastic curve is horizontal. Expressions (32) to (37) will therefore give all the moments for girders with walled in ends, when all the spans are equal, or when the spans nearest to the ends are different in length. Making $n = 0$, and changing the indices so that they correspond with the sketch, we



have for the moments

$$(38) \qquad \text{when } m < r+1, \quad M_m = c_{m-1} \frac{Qc_{s-r+1} + Q'c_{s-r}}{pc_{s-1} + 2pc_s},$$

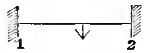
$$\text{when } m > r, \quad M_m = c_{s-m+1} \frac{Qc_{r-1} + Q'c_r}{pc_{s-1} + 2pc_s},$$

where Q and Q′ are given in (32) and (33), and the values of c are,

$$c_0 = 1, \ c_1 = -2, \ c_2 = 4 + 3p. \ c_3 = -14 - 12p. \ c_4 = 52 + 45p, \text{ etc.}$$

From these simple formulæ it is easy to get the values of the moments for any girder whose ends are fastened. These values can also be arranged in triangles, since they follow the same laws as for

free ends. From what has been said concerning the reactions the reader can have no trouble in determining them also. For example, making $s = 1$, we have a simple girder.



From (38) we get at once the moments, $M_1 = Pl(k - 2k^2 + k^3)$, $M_2 = Pl(k^2 - k^3)$. From (11) $R_1 = 3\frac{M_1}{l} - \frac{Q}{l} + q$, and $R_2 = 3\frac{M_2}{l} - \frac{Q'}{l} + q'$, or $R_1 = P(1 - 3k^2 + 2k^3)$, and $R_2 = P(3k^2 - 2k^3)$, the well-known expressions for that case. For uniform load in a single span it is only necessary to use the corresponding values of Q and Q′. When there are many spans uniformly loaded, the values due to each loaded span should be found and the results added.

COMPOUND AND NON-COMPOUND ENGINES, STEAM-JACKETS, ETC.

By Charles E. Emery, C. E., New York.

Herewith is presented a discussion of the results of experiments made at Baltimore, Md., in May, 1874, with the steam machinery of the U. S. Coast Survey steamer "Bache," under the general direction of the writer (see vol. lxix, page 105), and of the results of experiments made at the U. S. Navy Yard, Boston, Mass., in August, 1874, with the steam machinery of the U. S. Revenue steamers "Rush," "Dexter," and "Dallas," under the general direction of Chief Engineer Charles A. Loring, U. S. N., and the writer. (See vol. lxix, page 197. See also page 161, showing the tank used for measuring the feed-water during the experiments with the "Bache.")

The detailed reports have been published at different times, and necessarily involve so many details that we add, as convenient for reference from time to time as we proceed with the discussion, a recapitulation of the distinguishing features of the engines tested, and of the general scope of the two series of investigations.

Both series of trials were made with the vessels secured to the dock.

1. The Coast Survey steamer Bache was provided with a compound engine of the steepled type (that is, the smaller cylinder was arranged

above the other, and the pistons had a common rod). The larger cylinder was steam-jacketed, and so arranged that it could be operated independently, using steam of the same pressure and with the same degree of expansion as when both cylinders were working together as a compound engine. Trials were made of the two systems of working, both with the steam-jacket in use and when the same was disconnected, and the amount of water collected from the jackets and intermediate chamber was separately weighed and noted. All the experiments except one, were made with an approximate steam pressure of 80 pounds, and with different degrees of expansion for each system of working, with and without use of jacket. The indicated power was measured, also the cost of the same in steam (shown by the weight of feed-water used). The evaporative efficiency of the boiler was also determined.

2. One of the revenue steamers, the Rush, was provided with a compound engine, constructed on the "fore and aft" system (that is, the cylinders were at the same level, and in this case the pistons were connected to cranks at right angles). Both cylinders were steam-jacketed. The other two revenue steamers, viz., the Dexter and Dallas, had non-compound engines, with unjacketed cylinders. The compound engine of the Rush was operated in two different runs at the approximate steam pressures of 70 and 40 pounds. The single engine of the Dexter was operated with the same steam pressures and at different degrees of expansion for each pressure. The engine of the Dallas was operated at an approximate steam pressure of 35 pounds, and at different degrees of expansion. The boilers were all substantially alike. The performance was obtained by measuring the indicated power and its cost in steam, as shown by the weight of feed-water used. The evaporative efficiency of the boilers was also ascertained during the longer experiments.

From the two series of experiments may be gathered the following information, viz.:

1. The saving by the use of a steam-jacket on the cylinder of a non-compound engine, and the larger cylinder of a compound engine.*

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* The steam-jacket on the larger cylinder of the steamer Bache, and that on each of the cylinders of the steamer Rush, were supplied with steam in the following manner: steam was first admitted to the cavity in cylinder cover, from which, by means of a pipe leading from the bottom of the cavity, it was conducted to the side jacket, thereby keeping the cavity in cover clear of water. The side and bottom jackets communi-

2. The relative saving that may be obtained by the use of a compound engine, as compared with a single engine, operated at the same or a different steam pressure, or at the same or a different degree of expansion.

3. The probable value of a steam jacket on the smaller or high-pressure cylinder of a compound engine.

4. The influence which the size of a steam cylinder has upon the economy of fuel.

5. The relative cost of the power, at different steam pressures, in compound and non-compound engines.

6. The most economical point of cut-off for the steam pressures employed.

These subjects are discussed in the order named, and paragraphs to which it may be desirable to refer are designated by letters affixed to the numbers referring to the subjects. The table showing the results of experiments on U. S. Coast Survey steamer Bache will be designated "Table No. 1," and that showing the results of experiments with the Revenue steamers, "Table No. 2."

1. The Advantages of the Steam-Jacket—(1 A). Referring to Table No. 1, and comparing the minimum costs for each method of working, we find that the single cylinder of the Bache when operated without the steam-jacket required (Exp. 13, line 46), 26·247 pounds of feed-water per indicated horse-power per hour, and that with steam-jacket in use there was required (Exp. 16, line 46) but 23·154 pounds, showing that the saving by the use of the steam-jacket on a single cylinder engine worked at its most economical point of cut-off is 11·78 per cent. With more expansion, as shown by comparing the previous experiments for each method of working the jacket produces a greater saving, but the steam is in all cases being cut off too short for maximum economy, as will be discussed hereafter.

---

cated, and the water of condensation was blown from latter into the hot well, the flow being regulated by the Engineer to maintain a water level, in a glass gauge, on a small chamber in the drain-pipe.

On the Bache, when operated as a compound engine, the steam for the jacket was taken from bottom of steam-chest of upper cylinder, thereby keeping that drained. When the lower cylinder was operated as a single engine, the steam for jacket was taken from main steam-pipe. On the Rush, the steam for jackets was taken directly from the boiler.

It will be shown, in discussing experiments other than those above mentioned, that the system of draining the steam-chests, as well as the steam-jackets, is of considerable advantage.

(1 B.) When the engine of the Bache was operated as a compound engine, with steam-jacket not in use, experiment 2 shows a cost of 23 036 pounds of water per I. H. P. per hour, and experiment 6 with steam jacket in operation, a cost of 20·332 pounds. The saving in steam by the use of the jacket on the larger cylinder of a compound engine is then shown to be 11·73 per cent.

2. Saving by use of Compound Engine—(2 A.) The minimum cost of the power with the single cylinder of the Bache and steam-jacket in use, experiment 16, is 23·154 pounds, and with engine compounded, and steam-jacket on large cylinder in use, experiment 6, it is 20·332 pounds; so the compound engine was operated with a saving of 12·19 per cent. in this case, as compared with the single engine.

(2 B.) The above experiments were made at the same steam pressure, but with a less degree of expansion in the single engine, the steam being expanded nearly seven times (6·975) in the compound engine, and but little more than five (5·11) times in the single engine. With the steam expanded eight and one-half times (8·57) in the single engine (Exp. 15), the cost is 24·088 pounds using the same steam pressure, so the compound engine shows a saving compared therewith of 15·6 per cent. The difference increases as the expansion is increased in the single engine.

(2 C.) The minimum cost of the power with the single cylinder and steam jacket not in use, experiment 13, is 26·247 pounds, and with engine compounded, without steam-jacket, experiment 2, it is 23·036 pounds, so without using steam-jackets in either case, the compound engine operated with a saving of 12·23 per cent. as compared with the single engine.

(2 D.) With steam-jacket in use on larger cylinder of compound engine, experiment 6, and not in use on single engine, experiment 13, the costs, as before stated, were respectively 20·332 and 26·247 pounds, showing a saving by the use of the former under conditions stated of 22·54 per cent.

(2 E.) In the experiments with the revenue steamers it will be seen (Table No. 2, line 76, Exp 1 and 3) that the relative costs of the power in the compound engine of the Rush with both cylinders jacketed, and in the single engine of the Dexter, with unjacketed cylinder, were as ·7706 to 1·00, corresponding to a saving by the use of the compound engine with both cylinders jacketed, as compared with an engine with single unjacketed cylinder, of 22·94 per cent., or

practically the same as shown on the Bache with only the larger cylinder of the compound engine jacketed.

(2 F.) Assuming that a steam-jacket on the single cylinder of the Dexter would have reduced the cost in the same proportion that it did in the Bache, viz., 11·78 per cent., the cost of the power in the single cylinder engine which was 29·77 per cent. greater than in the compound engine (Table No. 2, line 74, Exp. 1 and 3) would have been reduced ($1 \cdot 2977 \times 11 \cdot 78 =$) 15·29 per cent., and the relative costs would have been as 1 to 1·1448, equivalent to a saving of ($1 \cdot 1448 - 1 \cdot 00 \times 100 \div 1 \cdot 1448 =$) 12·65 per cent., by the use of the compound engine with jacketed cylinder, as compared with the single engine with jacketed cylinder.

As above stated (2 A), the experiment with the Bache showed a saving of 12·19 per cent. under similar conditions.

The experiments do not furnish conclusive information as to what the relative performances of compound and non-compound engines of larger sizes would be. It seems probable, however, that in such case the compound engine would show still greater advantages.

In the revenue experiments above cited (2 E), the saving of 22·94 per cent. was reduced to 12·65 per cent. (2 F) by assuming that a steam-jacket on the cylinder of a single engine would save as much as it did on the Bache, which is not probable, for the reason that the cylinder of the Dexter was larger than that of the Bache, and it is an evident fact that the ratio of capacity to jacket surface decreases as the size of the cylinder is increased.*

This reasoning would not apply to the experiments made on the Bache with the same engine operated on both systems, but in that case the compound engine was not constructed for maximum economy, while the cylinder used for the single engine was probably as good as could be made. The latter was thoroughly steam-jacketed at sides and in bottom and cover. It also had large cylinder-ports, and the minimum amount of space in clearances and passages. Tight pistons were used in all cases.†

* To settle the question as to the economy of the steam-jacket on a single engine of practically the same size as the compound engine of the Rush, arrangements are being made for a series of trials on a Revenue steamer recently completed, the "Gallatin," which has machinery adapted for the purpose.

† It will be interesting to add that the direct steam connection for the larger cylinder of the Bache was originally designed by the writer as an auxiliary arrangement to be used in case of accident to the other cylinder, and the drawing provided therefor, a pipe of the same size as that for the upper cylinder. The contractors, Messrs. Pusey,

When the engine of the Bache was used as a compound engine, the upper cylinder, though well felted and lagged, was necessarily exposed to more refrigerating influence than in compound engines on the "fore and aft" system. The omission of the steam-jacket on the small cylinder may also have occasioned some slight loss, which subject is discussed hereafter. These disadvantages were considered in the first instance as of less consequence than the saving of space, etc., accomplished by adopting the system in that particular location, but in making a comparison of compound and non-compound engines, it is proper that they should be considered.

Bôth series of experiments appear to show then that the compound engines were at least not tried at any advantage as compared with the single engines; on the contrary, the indications are that still greater comparative economy would be shown by the compound system in larger engines.

3. Value of Small Cylinder Jacket.—These experiments appear also to corroborate the views held by the writer at the time the engine of the Bache was constructed, (1870), viz., that the steam-jacket on the smaller or high pressure cylinder of a compound engine, working with the ordinary degree of expansion, was, contrary to the views of Rankine on the subject,* of comparatively little value.

(3 A.) The experiments with the compound engine of the Rush, where both cylinders were jacketed, compared with the single engine of the Dexter with unjacketed cylinder showed a saving (see 2 E) of 22·94 per cent., and in experiments on the Bache, the compound engine with jacket on large cylinder showed a saving, compared with single cylinder used without jacket (see 2 D) of 22·54 per cent., so the additional jacket on the small cylinder of the Rush did not sensibly affect the comparison on this basis.

(3 B.) On the Bache we find that the saving by the use of a compound engine with large cylinder jacketed, as compared with a single

Jones & Co., of Wilmington, Del., voluntarily increased the size of this pipe so that the two systems could be fairly tested in the same apparatus, though the duties of the vessel were such that it was not convenient to make the trial till about 3½ years after. This same firm, shortly after the construction of the Bache, built also the first of the long stroke high-pressure engines which revived the interest in that system, and I observe that they applied the steam-jacket to the cylinder and connected the cylinder to frames, through legs cast on former to hinder the transmission of heat to latter, the same as was provided for in drawings furnished for the engine of the Bache.

* Rankine on "The Steam Engine," Art. 286.

cylinder used with jacket, is (see 2 A) 12·19 per cent., and by indirectly comparing the performance of the Bache and the revenue steamers, the compound engine of the Rush with both cylinders jacketed, shows a saving (see 2 F) of 12·65 per cent. The saving by the jacket on the small cylinder could not then be more than (12·65 —12·19 =) 0·46 per cent.

(3 BB.) It is probable, however, that in compound engines constructed on the "fore and aft" system, the steam-jackets on *both* cylinders heat the intermediate steam as it passes from one cylinder to the other, and thereby reduce the cost of the power.

(3 C.) The opinion as to the relative value of the steam-jackets on the two cylinders of a compound engine was founded upon the views of the writer expressed in print as early as 1866–7,* which were in substance, that the great difference between the theoretical and practical performances of the steam-engine could be satisfactorily accounted for by the differences of temperature to which the interior surfaces of the cylinder are practically subjected. The metal of the cylinder is cooled by the exhaust steam and must be reheated during the next stroke, which causes condensation of part of the incoming steam; the resulting water is re-evaporated, partially during the expansive portion of the steam stroke, but mostly during the next exhaust stroke, thereby cooling the cylinder again, and the result is to transfer heat (by the alternate condensation and re-evaporation described) directly to waste in the atmosphere or condenser.†

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* U. S. Patent No. 70,707.

† It had previously been suggested that a portion of the loss could be accounted for in the manner indicated. The writer, after reading the account of Tyndall's experiments, showing the facility with which aqueous vapor radiated and absorbed radiant heat, and finding by calculation that it was necessary to heat and cool the metal of a cylinder during each stroke, but a very small distance below the surface to occasion all the loss observed, became convinced that nearly all the loss could be accounted for in this way, and it occurred to him that if the interior walls of the cylinder were made of non-conducting material, the loss would be greatly reduced. Accordingly experiments were made by the writer in 1866, which have been referred to in several publications. The following brief description appeared in an article on Compound Engines in the *American Artisan* of March 8th, 1871 :

"The nature of the loss was proved in the following manner: I constructed two cylinders of like dimensions, one of glass, the other of iron, in such a manner that either could be attached to a valve which regularly admitted steam from a boiler to the cylinder and permitted its exhaust into a condensing coil lying in a tub of water.

A full discussion of this branch of the subject would occupy too much space in this paper. It was considered that the range of temperature in the smaller cylinder of a compound engine is generally less than in the larger cylinder and, moreover, that any heat transferred (so to speak) past the piston of the smaller engine would do useful work in the second cylinder. These views are apparently sustained by the experiments, but it should not be assumed that the jacket is of less value simply because high-pressure steam is used in the smaller cylinder, and that, therefore, a jacket is unnecessary for a high-pressure condensing engine. Quite the contrary is true, for in such case the interior surfaces of the cylinder are exposed to a variation of temperature equal to that in both the cylinders of a compound engine, and the jacket becomes of the greatest importance.

(3 D.) It is probable that the steam-jacket produces economy by drying and superheating the steam near the heated surfaces. If this be done promptly the heat imparted to the steam assists in performing useful work during the expansive portion of the stroke. Even during the exhaust stroke the dry steam near the surfaces of the cylinder will absorb very little heat compared to that required to evaporate particles of water which are always present when no jacket is used. The dry steam can only absorb heat at a rate proportioned to its specific heat, which is less than half that of water. The watery particles will take up both sensible and latent heat, or, for equal weights under actual pressures used, about two thousand times as many heat units as the dry steam. Could the steam in a cylinder be discharged simply saturated or slightly superheated, either by previous superheating or the use of efficient steam-jackets, the loss would be very small. At high expansions this is impracticable. Some water is always present and in its evaporation cools the metal surfaces somewhat, and it is always better to re-supply the heat from the steam-jacket than by condensation of incoming steam, as in the latter case the resulting water of condensation remains in the cylinder and causes increased losses in the manner previously indicated.

"The capacities of the two cylinders were made exactly the same, as was shown by transferring water from one to the other. When put in turn in the condition of a steam-engine cylinder, the iron cylinder used (averaging the experiments) fully twice as much steam as the glass one, shown by the fact that twice the quantity of water came through the condensing coil for the same number of movements of the valve. Steam of the same pressure was used in both cylinders, and the experiments were many times repeated with substantially the same results."

From these considerations it may be inferred that steam-jacketed cylinders would be most efficient if of comparatively small diameter and long stroke, in order to obtain as much surface in proportion to volume as possible; and that for unjacketed cylinders the surface in relation to volume should be reduced as much as possible.

4. ECONOMY OF STEAM AS INFLUENCED BY THE SIZE OF THE CYLINDER.—It is a well known fact that large engines are more economical per unit of power furnished than small ones. It is related that Watt was led to his invention of a separate condenser by observing the excessive quantity of steam required to operate a small model engine as compared with that found sufficient for engines of practical sizes—the vacuum being produced in both by admitting the condensing water directly into the steam cylinder. We have heretofore called attention to the fact that Watt, in producing condensation in a separate vessel, only partially overcame the difficulty; steam chilled by the performance of work being such an excellent radiator and absorbent of radiant heat as to cool the interior surfaces of a cylinder, upon reduction of pressure by condensation, even in a separate vessel, to a very material degree, if not to the same extent as if the water were directly admitted to the cylinder.*

The manner in which the loss takes place was discussed under the previous heading, and it is evident that the amount of heat transferred to waste in an unjacketed cylinder will, for a given range of temperature, vary as the amount of metal surface and inversely as the volume of steam exposed to the same. As the size of the cylinder is increased the volume increases in a more rapid ratio than the enclosing surfaces, hence the loss, relative to the unit of volume and power, decreases as the size of the cylinder is increased.†

(4 A.) The minimum cost of the power, using a single engine without a steam-jacket was on the Bache (Table No. 1, Exp. 13, line 45), 26·247 pounds of feed-water per horse-power per hour, and on the Dexter (Table No. 2, Exp. 3, line 53) it was 23·857. Again, on the

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* The subject was treated in this manner in a lecture delivered at the Sheffield Scientific School in the winter of 1870–71, which never having been completely written out was not published. See reference to Tyndall experiments with radiant heat in preceding foot-note.

† This statement has been demonstrated by numerous experiments, particularly hose referred to in the foot-note on page 105 of the present volume, and may be confirmed by comparing the results of similar experiments in the two series herein discussed.

Bache, using compound engine and jacket on the larger cylinder, the cost was (Table No. 1, Exp. 6, line 46) 20·332 pounds, and on the Rush (Table No. 2, Exp. 1, line 53) it was 18·384 pounds. The engine of the Bache was smaller than that of either of the other steamers, and, as shown, the cost was in both cases considerably more.* We have already pointed out that the relative performances for different methods of working in one series correspond well with those shown by the other, such, for instance, as the saving of the use of the steam-jacket and the relative economy due to a compound engine, but we now find that the actual costs shown in one series cannot be directly compared with those obtained in the other.

It may be accepted as a general fact that an experiment made with one engine cannot be used directly as a basis of comparison except for engines of similar size operated under similar conditions. The want of general information on this subject has often caused great misapprehension. Engineers have again and again made improper comparisons and often have conscientiously drawn directly opposite conclusions from the same data, when neither side had access to information sufficiently complete to refute the arguments of the other.

(4 B.) Referring to the experiments under discussion we find that the minimum cost of the power with the jacketed cylinder of the Bache, non-compound (Table No. 1, Exp. 16, line 46) was 23·15 pounds of water per horse-power per hour, and that with the unjacketed cylinder of the Dexter (Table No. 2, Exp. 3, line 53) it was but 23·86 pounds. Had there been but these two experiments to compare, many would naturally have held that there was little or no economy in the steam-jacket, and it is only by having the extended series of experiments on the "Bache" with and without the use of jackets on the same cylinder, that we are enabled to prove that there is economy in the use of the jackets; and by comparing experiments with engines of different sizes to show further that the actual performances of different engines are not directly comparable, while the relative performances for each engine, operated under different conditions, are properly comparable with similar relative performances of other engines.

(To be continued.)

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* The difference in performance between the Rush and the Bache may also be partially accounted for by the fact that there were steam jackets on both cylinders of the Rush, which were so arranged as to heat the intermediate steam, and thereby cause economy in the manner referred to above at (3 BB.)

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

During the time the writer was chief engineer of the Mare Island navy-yard, he made the experiments hereinafter described with the different screws applied by him to the United States steam-launch No. 4, attached to that yard. These experiments were promptly authorized, on the application of the writer, by Admiral Porter, then at the head of the Navy Department, without whose liberal support they could not have been made.

The machinery of the launch, designed by Mr. William R. Eckhart, the superintendent of machinery at the navy-yard and formerly an engineer in the Navy, was completed in the autumn of 1869, before the arrival of the writer. In the conduct of the experiments, all of which were projected and made by the writer in person, Mr. Eckhart rendered most valuable assistance.

The principal objects of the experiments were to ascertain, 1st. The relative economic propelling efficiency of screws of the same diameter, uniform pitch, and number of blades, but of different fractions of the pitch. 2d. The relative economic propelling efficiency of two-bladed, four-bladed, and Mangin screws, having the same diameter, uniform pitch, and fraction of pitch; in other words, having the same quantity and kind of surface. 3d. The relative economic propelling efficiency of a screw of the same diameter as the others, and having the same fraction of pitch as one of them, but three blades and a greater pitch expanding from the forward to the after edge of the blades. 4th. The relative economic propelling efficiency of this three-bladed screw, converted into a Griffith screw.

To ascertain the foregoing facts, there were to be determined for each screw and for different speeds of vessel with the same screw, the gross-effective indicated horse-powers developed by the engines; the pressure per square inch of pistons required to work the engines *per*

se, or disconnected from the screw; the resistance of the vessel *per se*, by dynamometer; the speed of the vessel; the slip of the screws, and the friction of their respective surfaces on the water. These quantities enable the distribution of the whole power exerted to be accurately computed, and the values of the parts applied to produce the different effects ascertained.

Incidentally to the experiments, the economic vaporization of the boiler with anthracite was ascertained; and the power exerted by the engines to give the three-bladed screw a certain number of revolutions per minute, with the vessel held stationary to the wharf.

Before narrating the experiments, it is necessary to give the following description and dimensions of the hull and machinery employed:

HULL.

The hull is of wood. Its submerged surface is not coppered, but was kept well painted and cleaned during the experiments. With the vessel at the below draught of water (at which the experiments were made), the top of the rail at the bow is 6 feet above the water-line; at the center of the vessel's length, 3 feet 3 inches; and at the stern, 4 feet 3 inches. There is a house on the deck, 6 feet 8 inches wide, 38 feet 9 inches long, and rising, as a mean, 3 feet 9 inches above the top of the rail. The rudder is of metal, and counter-balanced.

Length on load water-line, from forward edge of rabbet of stem to after side of sternpost,		54·40 feet.
Extreme breadth on load water-line,		11·88 feet.
Depth of hull, from load water-line to lower edge of rabbet of keel,	Forward,	2·457 feet.
	Mean,	3·156 feet.
	Aft,	3·855 feet.
Depth of the keel below the lower edge of its rabbet,	Forward,	0 500 foot.
	Mean,	0·729 foot.
	Aft,	0·958 foot.
Load-draught of water from the bottom of the keel,	Forward,	2·957 feet.
	Mean,	3·885 feet.
	Aft,	4·813 feet.

Area of the greatest immersed transverse section at load-draught, ...	24·98 sq. ft.
Area of the load water-line, ...	456·54 sq. ft.
Area of the immersed external surface of the hull proper, exclusive of keel and rudder, . . .	603·00 sq. ft.
Area of the immersed external surface of the hull, inclusive of keel (100·8 square feet) and rudder (132 square feet), ...	717·00 sq. ft.
Displacement, per inch of draught, at load water line,	38·045 cu. ft.
Displacement, per inch of draught, at load water line,	1 0891 ton.
Displacement, to load water-line, ...	814·100 cu. ft.
Displacement, to load water-line, ...	23·3053 tons.
Distance of the greatest transverse section abaft the middle of the length of the load water-line,	3·42 feet.
Height of the metacenter above the center of displacement, ...	4·93 feet.
Depth of the center of displacement below the load water-line, ...	1·09 feet.
Center of displacement abaft the middle of the length of the load water-line, ...	2·26 feet.
Angle of dead-rise at the greatest transverse section,	$13\frac{1}{2}$ degrees.
Ratio of the area of the greatest immersed transverse section to the area of its circumscribing parallelogram, ...	0 6663
Ratio of the area of the load water-line to the area of its circumscribing parallelogram, ...	0·7064
Ratio of the displacement to its circumscribing parallelopipedon, ...	0·3991
Ratio of the length of the hull on the load water-line to its breadth, ...	4·5791

In the following table will be found the areas of the greatest immersed transverse sections, areas of water-lines, displacements, and angles at bow and stern, for different water-lines; commencing at the load water-line previously given, and descending by vertical depths of 6 inches. These water-lines, it must be observed, are parallel to the load water-line corresponding to the vessel's draught of water, forward and aft, previously given:

Number of water-line.	Depth, in feet from lower edge of rabbet of keel to water line.		Area of greatest immersed transverse section, from lower edge of rabbet of keel to water-line in square feet.	Area of water-line in square feet.	Displacement, from lower edge of rabbet of keel to water-line, in cubic feet.	Angles of water lines.	
	Forward.	Aft.				Bow	Stern
						°	°
7	2·457	3·855	24·98	456·54	814·100	38	77
6	1·957	3·355	19·04	421·26	593·915	37	56½
5	1·457	2·855	13·26	370·86	395·360	34½	48
4	0·957	2·355	7·93	294·71	228·025	30	35
3	0·457	1·855	3·62	188·16	105·980	19¼	22½
2		1·355	1·25	81·90	[illegible]0·090	8	11½
1		0·855	0·35	28·04	15·470	4½	3½

From the following dimensions the form of the immersed solid of the hull can be ascertained. They are ordinates to the curves of the water-lines formed by the outside of the planking, and are given in feet from the forward and aft center line of the hull. That line is divided into sixteen equal parts of 3·4 feet each, and the corresponding transverse sections are numbered from 1 at the stem to 17 at the stern; from each point of division a right-angled ordinate is erected on which the dimensions referred to apply.

The water-lines are 6 inches apart, measured vertically. They are not parallel to the rabbet of the keel, but to the surface of the water when the vessel has the draught of water forward and aft as given above. Water-line A is at the water-level, water-line B is 6 inches below A and parallel to it, and so on.

Water lines 6 inches apart vertically, A being at the water-level.	Ordinates, in feet, from the central forward and aft line of the hull to the outside of the planking on each transverse section of the immersed solid of the hull, as numbered below, No. 1 being at the stem and No. 17 at the stern. Distance of the transverse sections apart, 3·4 feet.																
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.	No. 16.	No. 17.
A	0·12	0·72	1·79	2·94	4·02	4·88	5·45	5·76	5·90	5·94	5·90	5·78	5·50	5·08	4·25	2·68	0·30
B	0·12	0·57	1·41	2·50	3·58	4·50	5·24	5·66	5·84	5·90	5·84	5·66	5·26	4·60	3·42	1·75	0·12
C	0·12	0·40	1·06	2·00	3·01	4·00	4·75	5·25	5·54	5·61	5·52	5·22	4·63	3·76	2·47	1·03	0·12
D	0·12	0·25	0·67	1·36	2·18	3·04	3·85	4·50	4·91	5·00	4·82	4·31	3·54	2·60	1·56	0·62	0·12
E	0·12	0·18	0·39	0·75	1·28	1·85	2·44	2·92	3·25	3·34	3·20	2·78	2·20	1·54	0·90	0·42	0·12
F	0·12	0·16	0·24	0·35	0·50	0·68	0·90	1·14	1·40	1·50	1·42	1·25	0·98	0·70	0·46	0·28	0·12
G	0·12	0·12	0·12	0·12	0·12	0·13	0·14	0·21	0·34	0·45	0·48	0·46	0·39	0·30	0·22	0·14	0·12
H	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·13	0·14	0·14	0·13	0·12
I	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12

ENGINES.

There are two direct-acting, non-condensing engines. The cylinders are vertical, and are placed immediately above the crank-shaft, with their connecting-rods working downward. The cylinders rest upon columns supported in turn upon a cast-iron bed-plate, which contains the crank-shaft journals. The valve-chests of the cylinders are placed between the cylinders, back to back. There are two small slide-valves to each cylinder, one at each end, connected in the chest by rods. These valves work with the full pressure of the steam upon their backs, and receive their movement direct from two eccentrics and a Stephenson link. They have no lap on the exhaust side, but sufficient steam-lap to cut off the steam at 0·858 of the stroke of the piston from the commencement when in full gear. In this state the steam is released when the piston has completed 0·96 of its stroke, and the cushioning commences at 0·94 of the stroke. The Stephenson link is connected directly to the head of the valve-stem.

The cranks for the after-cylinder are forged in the crank-shaft. For the forward cylinder there is but one crank; it was forged separately and keyed on, and its pin is overhung. The crank-shaft has three journals, one for the forward cylinder and two for the after cylinder. The thrust-collars are forged on the crank-shaft, and their pillow-block is supported on the engines' bed-plate. There are no collars on the screw or line shafting.

The feed-pump is worked direct from an eccentric on the crank-shaft between the engines. This pump is slightly inclined, is single acting, and the eccentric-rod is articulated to the bottom of the pump-plunger.

The feed-water is fresh, and is carried in a tank; before it enters the boiler, it is passed through a heater supported on the top of the boiler, and has its temperature raised to about 125° Fahrenheit by the exhaust steam. This heater consists of an outer and inner pipe, placed concentrically; the exhaust-steam being within the inner pipe and the feed-water being in the annular space between the two pipes.

The exhaust-steam after passing through the heater is thrown into the chimney of the boiler, and accelerates its draught.

The sides of the cylinder are felted and lagged, also all the steam pipes.

The following are the principal dimensions of the engines, namely:

Number of cylinders, ...	2
Diameter of cylinders, ...	$6\frac{3}{4}$ inches.

Diameter of piston-rod, ...	$1\frac{1}{8}$ inches.
Stroke of pistons, ...	8 inches.
Net area of both pistons, exclusive of piston rods,	70·574 sq. in.
Space displacement of both pistons, exclusive of piston-rods, ...	564·592 cu. in.
Clearance of the pistons, ...	$\frac{3}{16}$ inch.
Length of steam-port, ...	4 inches.
Breadth of steam-port, ...	$\frac{5}{8}$ inch.
Area of steam-port, ...	$2\frac{1}{2}$ sq. in.
Length of exhaust-port, ...	4 inches.
Breadth of exhaust-port, ...	$\frac{7}{8}$ inch.
Area of exhaust-port, ...	$3\frac{1}{2}$ sq. in.
Space comprised in the clearances and passages of one end of both cylinders, ...	26·4 cu. in.
Number of crank-shaft journals, ...	3
Diameter of crank-shaft journals, ...	$2\frac{1}{2}$ inches.
Length of crank-shaft journals, ...	$3\frac{1}{4}$ inches.
Diameter of crank-pin journals, ...	2 inches.
Length of crank-pin journals, ...	2 inches.
Diameter of cross-head journals, ...	$1\frac{1}{4}$ inches.
Length of cross-head journals, ...	$1\frac{1}{4}$ inches.
Area of main guide-gib, ...	18·28 sq. in.
Diameter of main connecting-rod in the necks, .	$1\frac{3}{16}$ & $1\frac{5}{16}$ in.
Length of main connecting-rod between centers of journals, ...	19 inches.
Diameter of feed-pump (single-acting plunger),	$2\frac{1}{2}$ inches.
Stroke of feed-pump plunger, ...	$2\frac{1}{2}$ inches.
Width of eccentric-straps, ...	$\frac{3}{4}$ inch.
Length, forward and aft the vessel, occupied by the engines, ...	36 inches.
Breadth, athwartship, occupied by the engines, .	27 inches.
Height of the engines above axis of crank-shaft, .	42 inches.
Number of thrust-collars on screw-shaft, . .	5
Projection of thrust-collars beyond screw-shaft, .	$\frac{7}{16}$ inch.
Thickness of thrust-collars on screw-shaft, . .	$\frac{1}{2}$ inch.
Heating surface in feed-water heater, ...	260 sq. in.
Net weight of engines, including crank-shaft, but excluding everything else, ...	1400 pounds.

BOILER.

There is one boiler of the horizontal fire-tube type, with the tubes returned by the sides of the furnace.

The shell is a horizontal cylinder of 49 inches outside diameter, and 6 feet 6 inches extreme length, with flat ends. The front end is the front tube-plate for the tubes, and the uptake is of sheet-iron made separately, and bolted to the front of the shell.

There is one furnace, and it is contained in a cylinder of 2 feet inner diameter, and 4 feet $11\frac{1}{4}$ inches extreme length. In this cylinder are the grate-bars and the bridge-wall. The grate-bars are 4 feet 3 inches long, and the average breadth of the grate-surface is 1·96 feet.

The top of the grate-bars, at the front of the furnace, is one foot below the furnace crown; and, at the back of the furnace, 1 foot 4 inches below this crown; the breadth of each grate-bar is 9-16 inch, and the width of the air-spaces between them is $\frac{5}{8}$ inch. The least water-space between the furnace and the shell is at the bottom of the latter, and is 3 inches wide, including thicknesses of metal.

The opening for the furnace-door is a semicircle of 20 inches radius. The door is of wrought iron, hinged at the bottom and latched at the top. It has a perforated lining-plate for the distribution of air, and two registers for the admission of air above the incandescent fuel. The aggregate air-opening in the two registers is 13·5 square inches.

The bridge-wall is an iron casting faced with brick. Its top is 6 inches above the top of the grate-bars, and its width is 5 inches. The height from the crown of the furnace to the top of the bridge-wall is 10 inches.

The back smoke-connection has a flat top, a flat back, and a flat front. The sides and bottom are concentric with the boiler-shell, from which they are separated by a water-space 3 inches wide, including thicknesses of metal. The flat water-space between the back of the connection and the end of the shell is 3 inches wide, including thicknesses of metal. The extreme height of the connection in the clear is $29\frac{1}{2}$ inches. The front of the connection is the back tube-plate of the tubes.

The tubes are returned along each side of the furnace, the top of the upper row being $3\frac{1}{2}$ inches above the furnace-crown. The tubes are of iron, lap-welded. Six of them are $2\frac{1}{4}$ inches in outside diameter, and the remaining fifty-four are 2 inches in outside diameter. Their metal is 1-10 of an inch in thickness. The tubes of each row, horizontally, are placed opposite the spaces between the tubes of the

row, above and below. The least water-space between the tubes is $\frac{5}{8}$ of an inch in the clear. The tube-plates are of $\frac{1}{2}$ inch thick metal, and the length of the tubes in the clear of the plates is 4 feet $10\frac{3}{4}$ inches.

The uptake is a construction of sheet-iron separate from the boiler-shell, and bolted to it. The outer periphery is concentric with the boiler-shell, and the inner periphery is concentric with the furnace. The front projects over the fire room $4\frac{3}{8}$ inches at the bottom and 13 inches at the top. On this inclined surface are two uptake-doors opposite the tubes. They are hinged at the top and latched at the bottom, and are of sufficient area to embrace all the tubes. From the top of the uptake, (at the level of the top of the boiler shell) which is rectangular in horizontal section, the chimney is drawn in to a circle of $10\frac{1}{2}$ inches inner diameter at the height of 20 inches above the top of the shell. At this height the upper cylindrical part, 4 feet 6 inches high, is hinged on. The chimney, for the whole height above the top of the shell, is surrounded by an air-jacket of $14\frac{1}{2}$ inches outside diameter, perforated with a row of holes at top and bottom.

Immediately over the boiler-shell, and connected to it by a pipe of 8 inches diameter, is a boiler-plate cylinder with flat ends serving for steam-room additional to what the upper part of the shell contains. The inner diameter of this cylinder is 15 inches, and its inner length is 4 feet $11\frac{1}{4}$ inches. It is of $\frac{3}{8}$ inch thick iron, and its upper part contains a dry-pipe, of 3 inches diameter, extending its whole length and perforated along the upper side. The steam-pipe to the engines is an extension of this dry-pipe. The hole in the top of the boiler-shell within the 8 inches diameter pipe is 4 inches diameter, and through it the steam passes to the cylindrical steam-room from the shell. The space between the top of the boiler-shell and the bottom of the cylinder is $3\frac{3}{4}$ inches.

The cylindrical portion of the shell is of $\frac{3}{8}$ inch thick iron. Its flat ends, and the flat back of the smoke-connection, are of $\frac{1}{2}$ inch thick plate. All seams are double riveted.

In the front of the shell, opening into the uptake, is an elliptical man-hole with diameters of 11 and 14 inches. And in the lower portion of this front, beneath the uptake, are two elliptical hand-holes, with diameters of $2\frac{1}{2}$ and 5 inches.

The entire exterior of the boiler-shell is felted, lagged, and covered with sheet-iron.

(To be continued.)

Chemistry, Physics, Technology, Etc.

NEW PROCESSES IN PROXIMATE GAS-ANALYSIS.

By Professor Henry Wurtz, of New York.

[*Communicated in part, with Experimental Illustrations, to the American Gas-Light Association, October* 22, 1874.]

(Continued from Volume lxix, page 226.)

If, however, the gas be strongly sulphuretted, this plan will not do, as sufficient *sulphuric anhydride* is then set free to act appreciably on the hydrocarbons present, both by absorbing them and by engendering sulphurous acid.

After the whole train is put in action, during the actual analysis, should it be practicable to *watch* the apparatus during this stage, A may be kept immersed in the hot water in B, which will save subsequent expenditure of time in preparation for the final weighing. K must be watched from the first, and if it turns brown very rapidly—indicating *much* oxygen present—the current must be stopped when the meter has shown about one foot flow, and K L taken out to be weighed: resuming—after recording the meter—with a direct connection from J to M. This, because it may not be safe to trust K for more than one foot of gas *largely* contaminated with air.

In the absence of an adequate number of arrows in this cut, it will, I trust, be clear on a little examination, that the course of the gas is from M to the inlet of the meter at its axis in the rear, and out again, through the rubber tube O, to the final CaCl-tube P, and thence through the vertical glass tube R, at the top of which it may be kindled.

The usual rate of flow advisable, if attainable, with this train, is about one foot per hour; and the whole amount of gas analyzed should not be ordinarily more than ten cubic feet. This does not necessarily apply to the NH^3 and HS determinations, however; as in a well-purified street-gas the amount of these in ten feet only might be

scarcely appreciable. Therefore, after some ten feet has passed the meter, the latter having been read and recorded, direct connection should be established from F to M, the intervening members being thrown out. The flow may then be kept on through A, E, F, M, the meter, and P, even up to 50 or 100 feet, or until the registered volume is judged sufficient for these two constituents.

In these latter cases it is obvious that the common one-dial photometer-meter, as figured, will not answer; and it will be necessary to provide a meter having dials enough to register continuously up to 100 feet, as well as down to decimals of a foot.

In this case, unlike the operation with the crude gas, no general distilling or transferring process is required before the final weighings. It is only essential that A should be free from condensed moisture at the close, by reason of immersion in B; or that it should be subsequently freed therefrom, by means of a dry gas-current through and from the preparatory train.

V.—Of the Dimensions of the Apparatus, etc.

The sizes and weights of the different pieces of apparatus must not be left unexplained.

Flask C is of one pint capacity. It is convenient to have at least four different sizes or patterns of U-tubes. The largest, represented by H in the preparatory train, is about 13 inches high, 1·1 inch internal calibre, and 2·25 inches between the limbs. The second size is the most useful size, the corresponding dimensions being about $8 \times \cdot 9 \times 2$ inches, and is exemplified in Fig. 1 by F, G, H, L, M and the omitted CaCl tube; and in Fig. 4 by G, H, K, and P. The third size, C and D in Fig 2, and F in Fig. 4, may be $6{\cdot}5 \times \cdot 6 \times 1{\cdot}9$; and the smallest, represented in duplicate in A, and by J and L in Fig. 4, also by J and M in Fig. 1, is about $4 \times \cdot 4 \times \cdot 75$.

The relative proportion of the different members of a train to each other is worthy of careful consideration in planning an investigation, and much time and labor may often be thus saved. These proportions will differ with the conditions and with the nature of the gas very largely.

For convenience in weighing, wires may be attached, as has been shown in the cuts in one case only—the CaCl-tube in GF in Fig. 2. As before stated, these wires, unless of platinum, are objectionable in the atmosphere of a gas works, and the tubes can just as well

be simply laid across the pan of the balance. The balance should be capable of bearing safely a load of at least 300 grams or a little more, and indicating one milligram, that is, of turning perceptibly with the 300,000th of its load.

One of the worst obstacles to accuracy in weighing large glass apparatus delicately being the well-known attraction of glass for moisture, I have adopted, as hinted before, a very valuable device; simply to provide thin polished brass, or tin cases, closing tightly, but *not hermetically*, suited in size to different sizes of tubes, within which the latter are shut up while warm and dry.

VI.—Of the Calculation of the Results.

To obtain from the observed volume, as per meter, the true initial volume of the mixed gas and spray operated on, requires some calculation. Taking first the most complex case, that of a crude coal-gas from the hydraulic main, we shall have the following

VI. Of the Calculation of the Results.

To obtain from the observed volume, as per meter, the true initial volume of the mixed gas and spray operated on, requires some calculation. Taking first the most complex case, that of a crude coal-gas from the hydraulic main, we shall have the following

FACTORS.	DENSITIES.*
The observed volume, in cubic feet and decimals; which call v.	
The final Fahr. temperature of the gas; which call $t°$.	
The weight of liquid in grains; which call Lt. . .	(Water = 1) = 1·25
The weight of liquid water, in grains; which call Lw.	

*The densities adopted for NH^3, HS and CO^2 are the theoretical ones employed by Bunsen in his Gasometry. Other authorities differ perceptibly about all these. The density of aqueous vapor adopted, is very close to Regnault's figures. Bunsen used ·62205.

The weight of initial	watery vapor; which call *wv*** . .	(Air = 1)	= 0·6220
" " "	gaseous ammonia (NH^3) which call *am*. . . .	" "	= 0·5896
" " "	gaseous sulphuretted hydrogen; which call *s*.	" "	= 1·1749
" " "	gaseous carbonic acid; which call *c*. . . .	" "	= 1·5202
" " "	naphthaline vapor; which call *n*. . . .	" "	= 4·5700

Other constants required in our calculations are:

1. The coefficient of dilatation of coal gas for the Fahrenheit degree. I adopt

$$\frac{1}{491 \cdot 9}$$

2. The number of grains of pure water in a cubic foot at 60° Fahr., which I make 436320.

3. The number of grains of dry air in a cubic foot, at 32° Fahr. equal 565, according to Regnault.

As to the first, Ph. Jolly has recently given (*Chemisches Central-blatt*, 1874, p. 241; from Poggendorff's *Annalen*) new determinations, which for one Fahr. degree are:

For H gas, ...	·002031
For CO^2 gas, ...	·002059
For Air gas, ...	·002039†

As coal gas is almost half hydrogen, I have adopted ·002033, which equals $\frac{1}{491 \cdot 9}$.

** It must not be forgotten that an addendum to *wv* is derivable from the final weighing of the bisulphate of potash tube.

† The figure of Regnault for this constant for air is almost the same as this; that of Magnus is a trifle lower. For Fahr. degree:

Regnault ·0020389, or $\frac{1}{490 \cdot 46}$

Magnus ·0020377, or $\frac{1}{490 \cdot 75}$

For calculating the third constant, I have adopted as a basis a figure kindly calculated for me by Prof. A. M. Mayer,* directly from the original determination of Regnault, for a liter of dry air under normal tensions, equal 1·29278 gram. Cooke's Chemical Philosophy gives this figure equal 1·29319 gram.

From Mayer's figure I get, closely enough, for one cubic foot air, at 32° Fahr. 565 grains.

In the most complex case of all, as in Fig. 4, when a wet meter is used, and the gas measured with a certain content of aqueous vapor, afterwards determined by means of the CaCl tube P; we have, in this weight, still another factor, wv'.

The following crude expression may now be first jotted down: V being the corrected initial volume† sought, in cubic feet, at 60° Fahrenheit:

$$\text{(A.)}\qquad V = v + \frac{60 - t^\circ}{491\cdot9}v + \frac{Lt}{436320 \times \text{dens. } Lt} + \frac{Lw}{436320}$$

$$+ \frac{wv}{565 - \dfrac{(60 - t^\circ)\,565\,\text{dens. } wv}{491\cdot9}} - \frac{wv'}{565 - \dfrac{(60 - t^\circ)\,565\,\text{dens. } wv'}{491\cdot9}}$$

$$+ \frac{1}{\dfrac{(491\cdot9 - 60 + t^\circ)\,565}{491\cdot9}}\left(\frac{am}{\text{dens. } am} + \frac{s}{\text{dens. } s} + \frac{c}{\text{dens. } c} + \frac{n}{\text{dens. } n}\right);$$

which, on interpolating the density figures above, may be reduced to

$$\text{(B.)}\qquad V = 1\cdot12198v - \cdot002033t^\circ v + \cdot000002292\left(\frac{Lt}{1\cdot25} + Lw\right)$$

$$+ \frac{wv - wv'}{522\cdot134 + \cdot71443t^\circ} + 491\cdot9\left[\frac{am}{143876\cdot256 + 333\cdot124t^\circ}\right.$$

$$+ \frac{s}{286703\cdot2 + 663\cdot82t^\circ} + \frac{c}{370964\cdot525 + 858\cdot9t^\circ}$$

$$\left. + \frac{n}{1115187\cdot4 + 2582\cdot05t^\circ}\right].$$

* Prof. Mayer remarks that he found a slight error in Regnault's own reduction of his observations.

† It should here be explained, that by "initial volume" is not meant the volume of the gas *in the main*; where, of course, by reason of the higher temperature, the aqueous spray Lw, and even part of Lt, may not exist; but strictly the volume and state of aggregation assumed by the gaseous mixture, as it passes the initial members E and F of the train in Fig. 1.

In the case in which t° equals 28° Fahr., as when the final temperature is reduced quite down to that of melting ice, we may express it thus:

$$(C.) \qquad V = 1{\cdot}065065v + {\cdot}000002292\left(\frac{Lt}{1{\cdot}25} + Lw\right) + \frac{wv - wv'}{542{\cdot}14}$$

$$+ \frac{am}{311{\cdot}45} + \frac{s}{620{\cdot}65} + \frac{c}{803{\cdot}06} + \frac{n}{2414{\cdot}1}.$$

In the case of purified illuminating gas, as from street mains, in which the suspended tar and spray should be, and ordinarily are inappreciable, the second right hand member of the equation (C) disappears, as also the last factor representing the condensable naphthaline; and if, in addition, the gas has been measured dry, by means of a dry meter at the tail of the train, so as to eliminate wv', and also at 32° Fahr., we have (omitting also an inappreciable fraction in the first factor) the simplest case of all;

$$(D.) \qquad V = 1{\cdot}0651v + \frac{wv}{542{\cdot}14} + \frac{am}{311{\cdot}45} + \frac{s}{620{\cdot}65} + \frac{c}{803{\cdot}06}.$$

The correction for *Atmospheric Pressure* has not been introduced into the above, and is independent thereof. In exact work, the barometer must of course be observed at short regular intervals, and V should be further corrected by reduction to the standard pressure of 30 inches or 762 mm. This is simple. Calling the volume as thus corrected $\mathcal{V}$; and the mean of the barometric observations P. Then—

$$V : \mathcal{V} :: 30 \text{ inches} : P;$$

the volumes being inversely as the pressures; and—

$$\mathcal{V} = \frac{P}{30}V;$$

whence a rule easily remembered. Multiply the whole of the right hand sides of the above equations by

$$({\cdot}03333+)P.$$

Equation (D) may then—corrected further for atmospheric pressure P—become:

$$\text{(E)} \qquad V = \cdot 0355Pv + \cdot 033333P\left[\frac{wv}{542\cdot 14} + \frac{am}{311\cdot 45} + \frac{s}{620\cdot 65} + \frac{c}{803\cdot 06}\right].$$

To the above discussion, it seems proper to append the remark, that the data determined by it, while necessary to the gas-chemist, are not indispensably needed by the mere practical expert; who may be more concerned to refer the proportions of the constituents, as found, merely to the volume of *purified* gas, brought to, or near to, normal conditions of tension and moisture. This is a simpler affair. For the bottle of broken ice in the above train, Fig. 4, I substitute, in this case, a similar one filled with *clippings of clean sponge saturated with water*, to serve the double purpose of bringing the gaseous current both to the temperature of the air, and to the maximum content of aqueous vapor correspondent thereto. If this be accurately enough accomplished, the direct reading of the meter, whether the latter be wet or dry, will be the required volume; subject only to the barometric correction above specified. The final CaCl-tube is then not needed, though it might still be used as a check upon the process, and will give a general and *precise* datum from which the gas may be calculated to any standard of temperature and moistness.

VII. Examples of Analytical Results Obtained by one of these Methods.

To illustrate the work turned out by the Analytical Train in Fig. 1, operated as specified above, I shall cite some of the figures obtained by me in the course of an investigation made some months since upon an apparatus now in use at the Works of the Harlem Gas-Light Co., in New York; which covers a novel principle of action, consisting in forcing crude coal gas—before cooling to atmospheric temperature, and in a finely divided state—through the liquid products of the retorts, and of the incipient condensation of the gas itself, constituting a species of straining or filtering of the crude gas through a liquid medium.

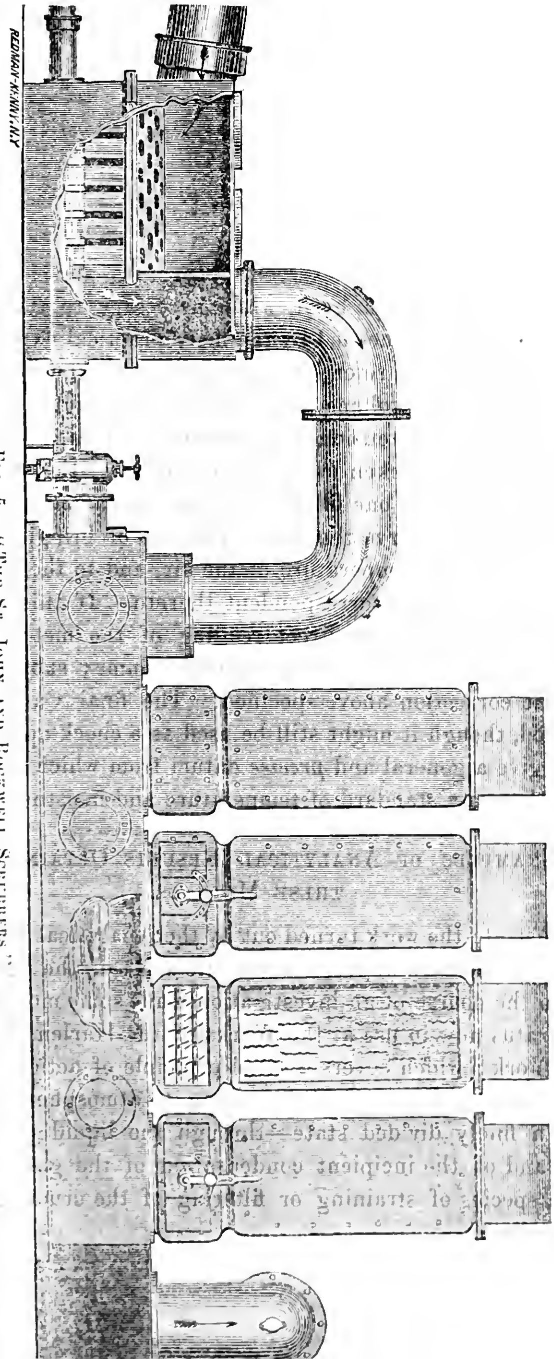


Fig. 5. "The St. John and Rockwell Scrubbers."

Weights: Grains per 100 cubic feet.	Crude Gas from Hydraulic Main.	Condensed Gas from Inlet to Purifiers.	Grains taken out of each 100 feet, by Scrubbers.	Percentage taken out of each Impurity.
1. Water	3515·2	2674·5	840·7	23·92
2. Tar	515·0	44·0	471·0	91·46
3. Smoke, soot, dust, etc.	265·9*	55·7	210·2	79·05
4. Naphthaline (condensable)	123·5	25·0	98·5	79·77
5. Ammonia (NH^3)	339·4	237·0	102·4	30·18
6. Sulphuretted hydrogen	1234·9	1105·1	129·8	10·51
7. Carbonic Acid	1698·0	1522·1	176·0	10·36
Totals	7691·9	5663·2	2028·7	26·39
Totals, without the water	4176·7	2988·8	1188·0	26·05
Average Temperatures, Fahrenheit	107°·5	94°·6		
Volumes: Cubic feet per hundred.				
Sulphuretted Hydrogen	1·93	1·73	0·20	10·88
Carbonic Acid	2·07	1·86	0 22	10·62

NOTE.—Dividing the above weights by 70, gives closely enough, the lbs. *per ton* of the Impurities.

* With some Naphthaline, as has been explained above.

In the cut, Fig. 5, is represented on the left, one of the "boxes" of St. John. The gas from the hydraulic main is pumped down through the vertical tubes and is obliged to rise through the perforated horizontal diaphragms immersed in the liquids that collect in the box, or arrive therein from the hydraulic main through the lower pipe.

The apparatus on the right is a form of "dry scrubber," appended to the "boxes." The number of boxes employed is two or more—at the Harlem Works two—this depending on the volume of gas to be dealt with. During my analyses some 20,000 cubic feet per hour passed the apparatus. Two trains after the plan of Fig. 1 were attached, one just before the extreme left-hand arrow, and the other near the extreme right-hand arrow. The results obtained were as seen in table; about seven feet of gas in all having traversed each train during the analyses:

The coal used was a highly sulphurous, but rich variety, from West Virginia, known as the "Murphy Run Coal." The temperatures during the operation were as follows:

Gas in the Hydraulic Main, ...	125° Fahr.
Gas entering first, or left-hand Train, . . .	108° "
Gas entering second, or right-hand Train, . .	95° "
Refrigeration while passing Condenser, . .	13° "

APPENDIX.—Note from Prof. Wurtz.

Mr. Editor:—On looking over the installment of my paper on "Proximate Gas Analysis," presented by you in your last issue, I have observed one passage involving error in the specification of my methods, to which I beg your permission to direct the attention of your readers: page 226; lines 10, 11 and 12 from top; from "K being" inclusive, on to the end of the paragraph substitute as follows:

"L replaced, KL weighed—after applying stoppers like DD in Fig. 1, to prevent ingress of aerial oxygen—and the whole put in position, as attached to J."

Also, after the last word "temperatures," at the bottom of this same page, it may be well to supply the following note, in parenthesis: (See *ante*, Graham's experiment; page 218 under *Sulphuretted Hydrogen*.)

Respectfully, H. W.

ON THE CAUSE OF THE LIGHT OF FLAMES.

By W. Stein.*

The correctness of the old and well-founded conception that the light of flame is caused by incandescent carbon molecules, has been disputed by Dr. Frankland, who contends and tries to prove that it is derived from hydrocarbon vapors. It is evident that the old theory would have to give place to the new doctrine as soon as the untenability of the former and the correctness of the latter are proved. But neither the one nor the other has, I think, yet been done. Professor Frankland can, therefore, only be pleased if the present paper subjects the *pros* and *contras* of the new and old theory to an impartial examination.

I must mention that I have not been able to read the original paper of Dr. Frankland, and have only had the opportunity of consulting "Dingler's Journal," the "Chemical Centralblatt," the "Annual Report of Chemistry," and the "Ann. Chim. Phys." According to these, Frankland considers that the light of the flame is derived from very dense hydrocarbon vapors, of which he particularly mentions benzine and naphthaline.

As proof of his ideas he mentions: That the soot deposited on a cool surface, when introduced into a flame, does not consist of pure carbon, but that it contains also hydrogen; that, in fact, it seems nothing else than a collection of the densest light giving hydrocarbons, whose vapors condense on the cold surface.

Against this we may mention that not only do the heavy hydrocarbons, but even marsh gas, split up at high temperatures on exclusion of atmospheric air; and as the hydrocarbons, whose vapors are supposed to cause the luminosity of the flame, are precisely under such conditions before they come in contact with the air, it cannot be doubted that they suffer decomposition into carbon and hydrogen in the luminous portion of the flame. It is of little importance whether the eliminated carbon is chemically pure, or whether it contains still a hydrogen compound; the important question is this, Is the soot held by the flame in the shape of vapor or in the solid form? If the soot was nothing but a conglomeration of the densest light-giving hydrocarbons, whose vapors condense on a cool body, then, when sufficiently highly heated by exclusion of air, it ought to reassume

[* Translated from the *Journal für Gasbeleuchtung* for the *London Journal of Gas Lighting*, and reprinted from the latter Journal.—Ed.]

vapor form. This is, however, not the case, as every one will find who tries the experiment.

Its chemical composition is just as little favorable to Frankland's view. It ought, presumedly, to vary according to the lighting material from which it was derived—nay, even according to the place of the flame wherefrom it was deposited. It is well known that the temperature of the flame varies in various places, and Magnus' experiments have proved that from heavy hydrocarbons at a less high temperature a hydrogenous tarry product besides hydrocarbon is also eliminated. The soot whose analysis I give was obtained from a bat's-wing burner by allowing a small silver basin, filled with water, to dip for about two or three minutes into the flame. Benzine removed traces of a solid yellow body, but the small amount of it prevented it being further investigated. Alcohol, and alcoholic solution of caustic potash, and dilute sulphuric acid, dissolved nothing.

After being carefully and repeatedly washed with boiling water and dried at 130°, 0·206 yielded: Carbonic acid 0·6985, water 0 0195, ash 0 0020, which amounts in 100 parts to:

	Containing Ash.	Free from Ash.
Carbon, ...	96·446	97 390
Hydrogen, ...	1·051	1·061
Ash, ...	0 970	——
Oxygen, ...	1·533	1·549

I attribute the presence of oxygen to a small amount of water, which, even at 130°, was still retained, and this when deducted gives the composition of 100 parts of soot free from water and ash as consisting of

Carbon, ...	99·095
Hydrogen, ...	0·905

This analysis is in accordance with the chemical composition of the soot of the flame, and with the well-known behavior of heated hydrocarbons.

2. "How could the light of a flame be as transparent as in reality it is, if it was filled with solid carbon particles?" asks Dr. Frankland.

In reply to this, it must be admitted that one is able to read the writing held behind the flame of a bat's-wing burner. It is, however, easily observable that the flame is more transparent in the lower, non-luminous portion. The reading becomes also more difficult through a flame of greater thickness, and impossible through the flame of a

candle or petroleum burner. If, as is proved hereby, the transparency of a flame is only very limited, it may be remembered that one can also read the same writing through media which are known to be filled with solid particles; for example, through a piece of opal glass, oiled paper, or linen. The partial transparence of the flame cannot, therefore, serve as a proof of the absence of carbon molecules.

3. To understand the further query of Frankland, "How could it be indifferent for photometrical measurement, whether the flame presents the flat or narrow side, if the light is given by solid carbon molecules?" we have to recollect an observation of Arago. At Paris they wanted to know what position the flame of the street-lamps had to be in to produce the best light for the *trottoirs* as well as for the carriage road. Arago made experiments, and found that the narrow side of the flame radiated as much light as the broad or flat side. This result caused general surprise, because it was assumed that light was only given off from the surface of a flame, the surface layers of carbon particles absorbing or retaining the light of the interior layers. It may, however, easily be understood that such a view arises only from a misapprehension of the process. A body can only lessen or stop the light which falls upon it from another body, if it is either only very little or not at all luminous. If both bodies possess equal luminous power, the result will be double in effect. Two carbon molecules placed one behind the other, and both radiating the same amount of light, cannot possibly weaken each other; their radiations, on the contrary, must be considered as two waves of equal amplitude and velocity, traveling either one immediately after the other, or combining in such a way as to double the height and depth. The luminous power of a flame must therefore be just as large on the narrow as on the flat side, because in both positions the number of the light-radiating carbon molecules is equal. The light appears, however, to the eye to be denser on the narrow side, because it is produced by a greater number of molecules vibrating, and after or behind one another.

4. To demonstrate that his view of the luminosity of vapors is not without example, Frankland refers lastly "to the development of light which is produced by the burning of arsenic, phosphorus, and bisulphide of carbon in oxygen, at ordinary pressure, and by the burning of hydrogen and carbonic oxide at higher pressures, in which cases the assistance of solid particles cannot be presumed."

Scientifically valuable and interesting as all this is, it does not demonstrate that the process of our luminous flame is an analogous one. Moreover, the fact that solid bodies are by preference apt to become light-radiating is not at all changed by this, and thus far it is demonstrated only that there can be but one solid body to which the luminosity of flame can be attributed. If we consider, therefore, all the before mentioned facts, we can draw only one conclusion—namely, "That the light of our illuminating flame comes from incandescent carbon molecules, and that the old view is still to be retained."

Experience teaches that for the artificial production of light, a high temperature is requisite before all things. Temperature is, however, that part of the total heat of a body which influences the surrounding parts, or the surplus of atomic movement which is not consumed by its inner work. A high temperature means, therefore, a great excess of such movement, which again is identical with a greater number of momentary vibrations. In fact, the movement of light and the movement of heat differ essentially by regularity (*Rhythmen*) and greater velocity. The movement of heat passes, therefore, presumedly into movement of light, if it has reached the lowest number of vibrations for light—namely, those of red light. If, after a greater and greater rising of temperature up to its highest possible degree, the rapidity of movement increases more and more, we observe, besides the red light, first, yellow light, forming orange with the former; later, we meet also blue light, which, however, in most cases, only serves to form white light with the red and yellow, and which is only predominant in very rare cases, as observed by Deville. Under ordinary circumstances, we only get a yellow or red light containing more or less white. The more white it contains the greater is, naturally, its effect of light; and, as white only appears at the highest temperatures, it becomes evident that the temperature of a flame does not exert a secondary influence on its luminosity, but is its principal factor. The second factor is the eliminated carbon, the molecules of which radiate the light. The luminosity of two flames of the same temperature corresponds, therefore, to the number of its carbon molecules, and "luminosity in general equal to the product of the radiating molecules and their temperatures" for illuminating purposes, it may be presumed that the latter should amount to at least 1000°.

The above-mentioned phenomena of light may easily be observed on solid bodies if heated. They are not observable on gases as long

as they expand unhindered. It would, however, be wrong to attribute this negative behavior to the circumstance alone that, by the unhindered expansion, the amount of the added, or produced heat was changed into power. This is contradicted by the high temperature which, amongst others, the non-luminous explosive gas-flame *Knall gas*) possesses.

Besides, it is also observed that platinum wire becomes incandescent in every possible non-luminous flame, even in a flame produced by nitrogen on coal gas, if the requisite temperature to change heat into light is present.

If we may conclude from this that the atoms of gases may be brought into light vibrations without becoming luminous, then we possess bodies which conduct the light (the gases), and others which radiate the light (the solid bodies), analogous, as we have conductors of electricity and idioelectrical bodies.

An explanation of this difference is offered when light is considered as atomic movement. Its effect to the eye is then the product of quantity and velocity.

In a given space we find a much larger number of vibrating atoms if filled with solid matter than if filled with gas. The waves of light of solid bodies must, therefore, be much denser than those of gases, and exert also a more intense effect on the nerves of our eyes. "Light-conductors" differ, therefore, from "light-radiators" by the lesser density of their waves of light; for which reason they cannot, under ordinary circumstances, form "optical molecules," as I expressed it at another occasion. How powerfully the condensation of the waves of light affects the eye is shown by the effect of collecting lenses.

The minimum of density which a body must possess to become light-radiating—that is, to become self-luminous to the eye, or to appear a source of light—is just now not known; but one sees, if this view is correct, the possibility of even vapors or dense gases becoming luminous, as Frankland tried to prove. The results of his experiments might even serve as foundation for the lowest limit of density, if it were not so very difficult, nay, even just now impossible, to make such an experiment in a manner as to exclude every doubt about the assisting influence of solid bodies.

SAFETY-VALVES.*

(Report of a Committee of the Institution of Engineers and Shipbuilders of Scotland.)

At the first general meeting of the present session of the Institution of Engineers and Shipbuilders in Scotland, a report on safety-valves was presented by a committee appointed to deal with this question. The report consists of (1) experiments made upon the outflow of steam through orifices; (2) experiments made "to ascertain the pressure to which steam will rise in a boiler above the load pressure when the valves are of the same size, having an area of half-an-inch per foot of grate surface, but at different pressures, the whole of the steam raised being allowed to pass away by the safety-valves when unassisted;" (3) experiments made "regarding the strength and action of springs as applied to the loading of safety-valves;" (4) conclusions arrived at by the committee as to the form, manner of loading, and dimensions of safety-valves. The first part of the report contains the account of an exhaustive series of experiments, made by Mr. James Brownlee, to determine the outflow of steam at different pressures through orifices of various forms, and commences with a recapitulation of the views held on this question by various scientific observers. In this part of the report it is pointed out that "until within the last twenty or thirty years the flow of weight and velocity with which steam and other elastic gases issue through an orifice was computed by the same rule which applies to water or other inelastic liquids." Weisbach, however, showed that this was incorrect, and believed that "the *quantity* of steam which flows through an orifice from a boiler under a pressure of two atmospheres is much greater when that orifice opens into the atmosphere than when the same orifice communicates with the condenser of a steam-engine." According to Mr. R. D. Napier's view, "the flow is neither increased nor diminished by reducing the outside pressure to less than half the inside pressure." Professor Rankine's view was that "the flow is neither increased nor diminished by reducing the outside pressure below about 58 per cent. of the absolute pressure in the boiler."

In conformity with this view a table is given in the report, showing, amongst others, the weight of steam in pounds discharged per minute

[* Reprinted from *Iron.*—Ed.]

through the best form of orifice, one square inch in area, and at absolute pressures varying from 25·37 lbs. to 100 lbs., the weight at these pressures being respectively 22·81 and 86·34 lbs. A table is given of the reaction of steam from experiments made by Mr. George Wilson.

Mr. Brownlee, to satisfy himself on this subject, made a series of nearly daily experiments, extending over a period of about six months. The method adopted was to allow steam, drawn from six boilers, to pass through a $1\frac{1}{4}$-inch valve into a chamber where the pressure could be kept steady. From this chamber the steam passed through a carefully-measured orifice into a second chamber, where the pressure could also be regulated. The steam finally entered a "worm" placed in a tub containing a circulating supply of cold water. The steam was thus delivered condensed, and at a temperature from 70 to 100°. The water thus obtained was measured and weighed, and the time observed. By this arrangement a flow of steam from a higher into a lower pressure was obtained. Examples of this are given in the report, from which it appears that it is doubtful whether the outflow of steam at 80 lbs. is affected by increasing the outside pressure from 17 to 48 lbs. It was found that the flow of weight through a square-shaped orifice was from 11 to 13 per cent. less than through an orifice with a rounded entrance. A third chamber was added to the apparatus, from which it appears that when the absolute pressure was maintained steady at 100 lbs. in the first chamber, the pressures obtained in the second and third chambers were 81 lbs. and 18 lbs. respectively, "showing that the steam which flows from 100 lbs. into 81 lbs. is the same in quantity as passes from 81 lbs. into 18 lbs., the two orifices being of the exact same size and form."

From the results obtained from these experiments the proper size of safety-valve openings was determined, from which it appears that "the weight in pounds of steam discharged per minute per square inch of opening, with square-edged entrance, corresponds very nearly with three-fourths of the absolute pressure in the boiler, as long as that pressure is not less than 25·37 lbs.," and that "the area of opening, requisite to the discharge of any given constant weight of steam is very nearly in the inverse ratio of the pressure." By allowing an evaporation of 3 lbs. of water per minute per square foot of

grate, the following rule for area of orifice of valve is obtained:—

$a = \frac{4 \times \text{square feet of grate}}{p_1}$ where a = area of orifice in square inches, and p_1 = the absolute pressure.

The second part of the report contains the result of a series of experiments made by Mr. D. Rowan, to ascertain the increase of pressure in the boiler over the load on safety-valve. These results are tabulated, and the increase of pressure stated as a percentage, which ranged from 160 with a load of 5 lbs., to 15·5 with a load of 45 lbs. The boiler was tubular, having 25 square feet of grate surface, and 746 feet heating surface; two valves were used of $2\frac{7}{8}$ inches diameter. This part of the report closes by showing that this increase of pressure is principally caused by the use of valves of too small dimensions.

The third part of the report treats of "Loading safety-valves by direct springs," and contains rules for the proportioning of springs from experiments made by Mr. Walter Brock. The "lift" having been fixed, a percentage of the load remains to be decided upon, "which is not to be exceeded by the additional load due to the compression or extension of the spring caused by the lift of the valve," this is assumed as $2\frac{1}{2}$ per cent. of the original load; from this it follows that "the compression or extension to produce the initial load, shall be forty times the lift of the valve." The following formula is given for the compression or extension of one coil of the spring:—

$E = \frac{d^3 \times w}{D^4 \times D}$. Where E = Compression or extension of one coil in inches, d = diameter from center to center of steel composing spring in inches, w = weight applied in pounds. D = diameter or side of square of steel, of which the spring is made, in 16ths of an inch. C, a constant, from which experiments may be taken as twenty-two for round steel, and thirty for square steel. The total compression or extension is obtained by multiplying by the effective number of coils, which is taken as two less than the apparent number. Examples of the application of these rules to the loading of valves are given at close of this part of report.

The report concludes by an expression of opinion of the committee, from which we make the following extracts: "The present practice in this country of constructing safety-valves, of uniform size for all pressures is incorrect. The valves should be flat-faced, and the

breadth of the face need not exceed one-twelfth of an inch. The present system of loading valves on marine boilers by direct weight is faulty, and ill adapted for sea-going vessels. That two safety-valves be fitted to each marine boiler, one of which should be an easing valve. The dimensions of each of these valves, if of the ordinary construction, should be calculated by the following rule:—

$$A = \frac{18 \times G}{P}, \text{ or } A = \frac{0{\cdot}6 \times HS}{P}. \quad \text{Where}$$

$A =$ area of valve in square inches.
$G =$ grate surface in square feet.
$HS =$ heating surface in square feet.
$P =$ absolute pressure in lbs. per square inch.

"The committee suggest that only one of the valves may be of the ordinary kind, and proportioned as above, and that it should be the easing valve. The other may be so constructed as to lift one quarter of its diameter without increase of pressure. Valves of this kind are now in use, and one such valve, if calculated by the following rule, would be of itself sufficient to relieve the boilers, $A = \frac{4 \times G}{P} +$ area of guide valve or $A = \frac{\cdot 133 \times HS}{P} +$ area of guides of valve. If the heating surface exceeds 30 feet per foot of grate surface, the size of safety-valve is to be determined by the heating surface. Springs should be adopted for loading safety-valves. and should be direct-acting where practicable."

Automatic Writing Machine.—M. Th. Huppinger, says the *Revue Industrielle*, has just invented a machine for writing spoken words. The mechanism is not large, being about the size of the hand. It is so put in communication with the vocal organs, either the lips, the tongue, the larynx, etc., that their movements are transmitted through a series of articulated levers, and recorded upon a band of paper unrolled for the purpose. The writing consists of dots and dashes. As the instrument reproduces only the movement of the vocal organs, it is not necessary, in using it to speak loud. It may consequently be used for stenographic purposes, the person to whom it is attached simply repeating the words of the speaker after him, but inaudibly.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXIX. MAY, 1875. No. 5.

EDITORIAL.

ITEMS AND NOVELTIES.

The United States Commission on Tests of Iron, Steel, etc.—The Congress of the United States made provision as is well known, by an Act approved March 3d, 1875, for the appointment by the President of a Commission to experiment and report upon the metals used in construction, the commission to be composed of men eminent in the specified direction. An appropriation of $50,000 was made to defray the expenses of this commission. In accordance with this Act of Congress, the President appointed Commander L. A, Beardslee, U.S.N., well known for his investigations on tensile strains, Lieut. Col. Q. A. Gillmore, U.S.A., the eminent military engineer, A. L. Holley, C.E., whose reputation as a metallurgical engineer is national, Lieut. Col. T. T. S. Laidley, U.S.A., the accomplished commandant of the arsenal at Watertown, Mass., Chief Engineer David Smith, U.S.N., a man pre-eminent among dynamic engineers, W. Sooy Smith, C.E., and Prof. R. H. Thurston, C.E., who has, by his new testing machine, revolutionized the theory of strength of materials, as the members of this commission. A meet-

ing for organization was held at the Watertown Arsenal, and at that meeting, Lt. Col. T. T. S. Laidley was elected President of the Commission, and Professor R. H. Thurston, Secretary. In one of the circulars they have issued, the statement is made that the commission "is instructed to determine by actual tests the strength and value of all kinds of iron, steel, and other metals which may be submitted to it, or by it procured, and to prepare tables which will exhibit the strength and value of said materials for constructive purposes."

In a second circular, they say:—

"The Commission desires to secure the assistance of all who are interested in this great work, and through them to obtain all information available as the result of the labors of earlier, or of contemporaneous, investigators and observers. I take the liberty of enclosing herewith circulars indicating the scope of the labors undertaken by this Commission, and beg that you will aid, by such methods as may be by you deemed best, in the collection of all information which may be accessible, relating to either the general work of the Commission or to the special subjects assigned to its committees. Data collected in the course of ordinary business practice, and the records of special researches previously made or now in progress, are particularly desired.

"It is expected that the Commission will receive valuable information and useful suggestions, both from business men and from men of science, and it is hoped that the work undertaken, as here indicated, may be supplemented by original investigations made by both these classes. The national importance of this work justifies the expectation of an earnest and effective co-operation.

"Very respectfully yours,

"R. H. THURSTON,

"*Secretary.*"

The following are the Standing Committees of the Board.

(A.) On Abrasion and Wear.—R. H. Thurston, C.E., Chairman, A. L. Holley, C.E., Chief Engineer D. Smith, U.S.N.

Instructions.—To examine and report upon the abrasion and wear of railway wheels, axles, rails and other materials, under the conditions of actual use.

(B.) On Armor Plate.—Lt. Col. Q. A. Gillmore, U.S.A., Chairman, A. L. Holley, C.E., R. H. Thurston, C.E.

Instructions.—To make tests of Armor Plate, and to collect data derived from experiments already made to determine the characteristics of metal suitable for such use.

(C.) On Chemical Research.—A. L. Holley, C.E., Chairman, R. H. Thurston, C E.

Instructions.—To plan and conduct investigations of the mutual relations of the chemical and mechanical properties of metals.

(D.) On Chains and Wire Ropes.—Commander L. A. Beardslee, U.S.N., Chairman, Lt. Col. Q. A. Gillmore, U.S.A., Chief Engineer D. Smith, U.S.N.

Instructions.—To determine the character of iron best adapted for chain cables, the best form and proportions of link, and the qualities of metal used in the manufacture of iron and steel wire rope.

(E.) On Corrosion of Metals.—W. Sooy Smith, C.E., Chairman, Lt. Col. Q. A. Gillmore, U.S.A., Commander L. A. Beardslee, U.S.A.

Instructions.—To investigate the subject of the corrosion of metals under the conditions of actual use.

(F.) On the Effects of Temperature.—R. H. Thurston, C.E., Chairman, Lt. Col. Q. A. Gillmore, U.S.A., Commander L. A. Beardslee, U.S.N.

Instructions.—To investigate the effects of variations of temperature upon the strength and other qualities of iron, steel, and other metals.

(G.) On Girders and Columns.—W. Sooy Smith, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Chief Eng'r D. Smith, U. S. N.

Instructions.—To arrange and conduct experiments to determine the laws of resistance of beams, girders and columns to change of form and to fracture.

(H.) On Iron, Malleable.—Commander L. A. Beardslee, U. S. N., Chairman, W. Sooy Smith, C. E., A. L. Holley, C. E.

Instructions.—To examine and report upon the mechanical and physical proportions of wrought iron.

(I.) On Iron, Cast.—Lt. Col. Q. A. Gillmore, U.S.A., Chairman, R. H. Thurston, C.E., Chief Eng'r D. Smith, U.S.N.

Instructions.—To consider and report upon the mechanical and physical properties of cast iron.

(J.) ON METALLIC ALLOYS.—R. H. Thurston, C.E., Chairman, Commander L. A. Beardslee, U.S.N., Chief Eng'r D. Smith, U.S.N.

Instructions.—To assume charge of a series of experiments on the characteristics of alloys, and an investigation of the laws of combination.

(K.) ON ORTHOGONAL SIMULTANEOUS STRAINS.—W. Sooy Smith, C.E., Chairman, Commander L. A. Beardslee, U.S.N., R. H. Thurston, C. E.

Instructions.—To plan and conduct a series of experiments on simultaneous orthogonal strains, with a view to the determination of laws.

(L.) ON PHYSICAL PHENOMENA.—W. Sooy Smith, C.E., Chairman, A. L. Holley, C.E., R. H. Thurston, C.E.

Instructions.—To make a special investigation of the physical phenomena accompanying the distortion and rupture of materials.

(M.) ON RE-HEATING AND RE-ROLLING.—Commander L. A. Beardslee, U.S.N., Chairman, Chief Eng'r D. Smith, U.S.N., W. Sooy Smith, C.E.

Instructions.—To observe and to experiment upon the effects of reheating, re-rolling, or otherwise re-working; of hammering, as compared with rolling, and of annealing the metals.

(N.) ON STEELS PRODUCED BY MODERN PROCESSES.—A. L. Holley, C.E., Chairman, Chief Eng'r D. Smith, U.S.N., W. Sooy Smith, C.E.

Instructions.—To investigate the constitution and characteristics of steels made by the Bessemer, open hearth, and other modern methods.

(O.) ON STEELS FOR TOOLS.—Chief Eng'r D. Smith, U.S.N., Chairman, Commander L. A. Beardslee, U.S.N., W. Sooy Smith, C.E.

Instructions.—To determine the constitution and characteristics, and the special adaptations of steels used for tools.

"The above named Committees of this Board are appointed to conduct the several investigations, and the special researches assigned them in the interval during which the regular work of the Board is delayed by the preparation of the necessary testing machinery, and during such periods of leisure as may afterwards occur.

"These investigations are expected to be made with critical and scientific accuracy, and will, therefore, consist in the minute analysis

of a somewhat limited number of specimens and the precise determination of mechanical and physical properties, with a view to the detection and enunciation of the laws connecting them with the phenomena of resistance to flexure, distortion and rupture.

"The Board will be prepared to enter upon a more general investigation, testing such specimens as may be forwarded to the President of the Board, or such as it may be determined to purchase in open market, immediately upon the completion of the apparatus ordered, at which time circulars will be published giving detailed instructions relative to the preparation of specimens for test, and stating minutely the information which will be demanded previous to their acceptance."

The Board has advertised for suitable testing machines, and other apparatus for the more extended investigations. Meanwhile, several of the above Committees have issued circulars concerning the special subjects they have in charge. Committee A says in its circular:—

"The Board has assumed, as a part of its work, the investigation of the methods and effects of ABRASION AND WEAR of metals in engineering and mechanical operations.

"This Committee is instructed to take up this subject and to report such valuable data and statistics, and such information as it may acquire by experiment or from other observers, in such form that it may be readily collated and made useful to the Government, the public, and the engineering profession.

"The Committee would be pleased to receive from any reliable source precise data and such information as may enable the Secretary to compile, in as concise and exact form as possible, a statement of the mode of deformation, the rapidity of abrasion, and the laws governing wear in any important typical or exceptional cases.

"The executive officers of all lines of railway may render valuable aid by furnishing statements of the wear of rails per ton of transportation specifying with care the original weight, the make, and the character of the rail, the total amount of transportation, the length of time occupied, and stating whether the rail finally broke or was removed. Specimens of rails remarkable either for endurance or for a lack of this quality, if sent to the Committee, will be of use in assisting in the determination of the chemical and other properties which most affect the value of the material under the stated conditions of use.

"Similar statistics and information in regard to the wear of wheels, axles and other parts of rolling stock and machinery will be equally valuable.

"Engineers having in any instance noted and accurately recorded such data, are requested to transmit to this committee copies of their memoranda.

"The wear of journals under heavy loads, or at high velocities, as well as under ordinary conditions, is an important branch of this subject. When possible, it is desired that the dimensions of the journal, the maximum, the minimum and the mean weight sustained, and the velocity of rubbing or number of revolutions per minute should be given. The nature of the lubricant is an essential element, and its composition should be stated, the method and frequency of application and the quantity used should be given. When known, or readily ascertained, the coefficient of friction should be given. It should also be noted whether heating occurs, and under what circumstances of pressure and velocity of rubbing surfaces.

"Peculiar instances of the behavior, or unusual expedients in the management of bearings, if described accurately and concisely, will be accepted, with thanks.

"The wear of tools, under the various conditions of workshop practice, is another subject of investigation.

"Weighing the tools carefully before and after use, and weighing the amount of metal removed will, perhaps, be found the most accurate method of determining the rate of abrasion. The area of surface finished, and the area of the surface cut by the tool should be accurately ascertained and stated.

"The description of the tools, its shape, method of operation, the kind of metal used in the tool, the temper adopted, the character of the metal cut by it, the velocity of the tool, and where peculiarities of behavior were noted, a careful statement of them should be given. This information will still be more valuable if the tool itself and specimens of the chips produced by it are furnished.

"The power required to drive the tool can sometimes be readily determined, and such information is of great value.

"The recent investigations of M. Tresca—*Memoir Sur le Rabotage des Metaux*, etc.—is an excellent example of such research.

"For all information which may properly fall within the limits of their investigation, this committee will return suitable acknowledgment.

"R. H. THURSTON,

"*Chairman.*"

We have also received a circular from the committee marked "J;" in which it is stated that the committee "has been instructed, during such time as may be found available pending the construction of the apparatus ordered by the Board for use in general work, and during such intervals as may be subsequently be properly appropriated to such purpose, to investigate the mechanical, physical and chemical properties of the alloys of the useful metals, and to determine, if possible, their interdependence and the laws governing the phenomena of combination and of their resistance to stress.

"The Committee desire to obtain records of all experiments which have hitherto been made in this direction, and to secure such exact information as may assist further researches. It is desirable that such records should embody a statement of the precise chemical constitution of each alloy examined, as obtained both by synthesis and subsequent analysis. Its specific gravity, specific heat, conductivity, its combining number, and the relation of its chemical constitution to the series of similar compounds produced by alloying the elements in the proportions of chemical equivalents, should be stated whenever possible. A few thoroughly well studied examples will be of more service than a large number of isolated determinations of single facts.

"It is further desired that the ultimate strength, the elastic limit, the modulus of elasticity, the ductility, resilience, homogeneousness, hardness and other mechanical properties of the specimen be ascertained and accurately stated.

"Where only a part of this work can be done by the investigator, this Committee is prepared to assume charge of the remaining portion of the research, when the alloy can be furnished in proper quantity and form.

"References to published accounts of similar works and monographs on any branch of the subject will be thankfully accepted. Special researches made for this Committee will be received with appropriate acknowledgments.

"The DEPARTMENTS OF PHYSICS and of CHEMISTRY in the various colleges and universities will probably be able to render valuable aid, and their co-operation is earnestly requested.

"The SCHOOLS OF ENGINEERING are in a position to assist this Committee very effectively and their contributions will be thankfully accepted.

"Suitable blanks upon which to record the data offered, will be furnished upon application.

"Specimens of alloys for test by the Committee must be accompanied by a statement upon these blanks of their precise constitution, and such information as it is possible to give, with an account of such peculiarities as are known to distinguish the alloy, and of the special object which it is supposed may be attained by the investigation.

"Where possible, it is required that one or more specimens shall be furnished of each of the specified kinds, and of precisely the form and dimensions, which will be given on application.

"R. H. THURSTON,

"*Chairman.*"

We cannot too heartily endorse the enlightened action of Congress in appointing this Commission, nor that of the President in his most judicious selection of its members. There is every reason to expect from this Board the most full and complete investigation of the sub-

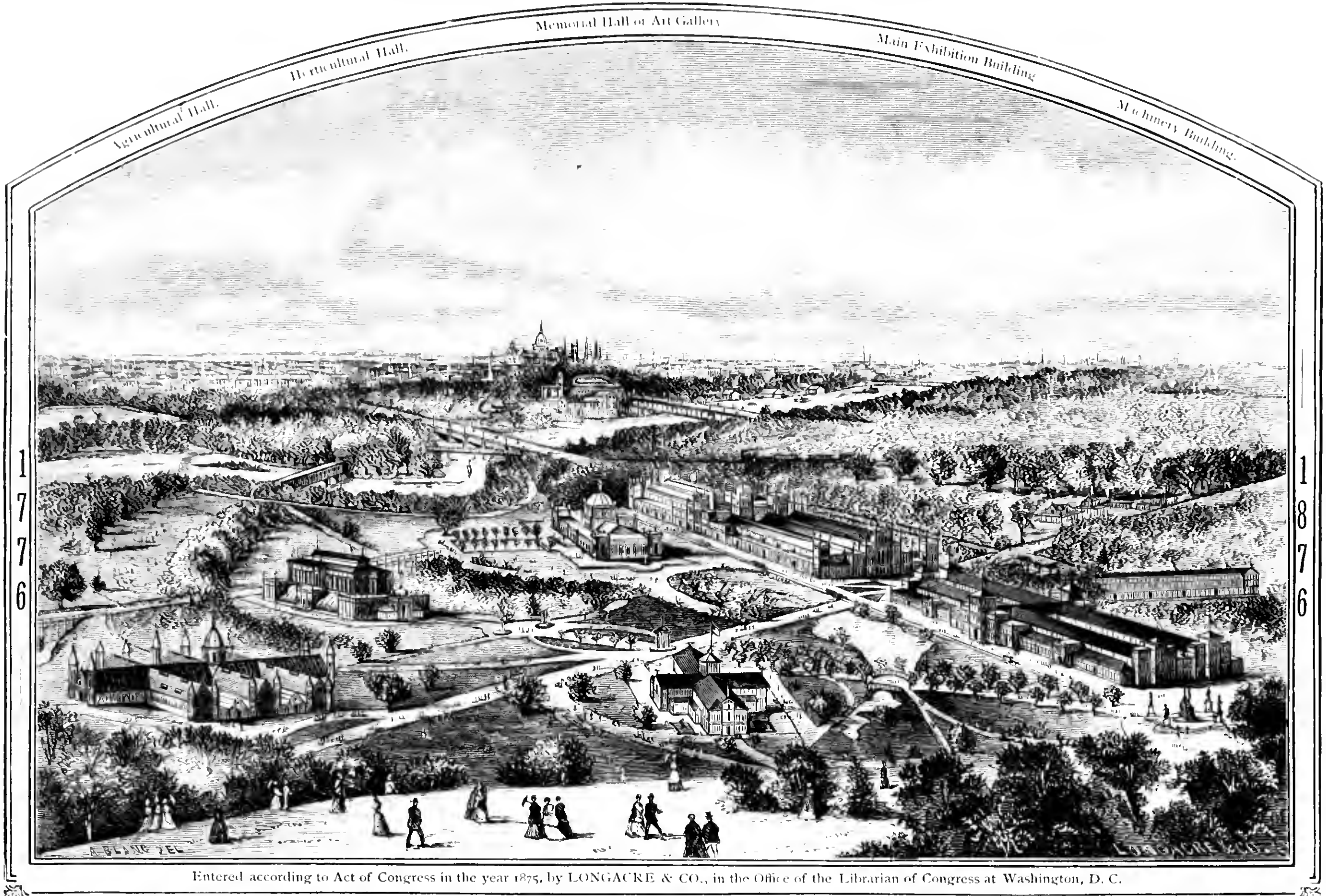
jects which come under its charge, which has ever been made in the history of engineering. We earnestly hope that a broad and patriotic liberality rather than a narrow selfishness will be the motive enlisting the cordial co-operation of all of our metallurgists and manufacturers who can in any way aid in developing results so valuable in themselves and so important to the country at large.

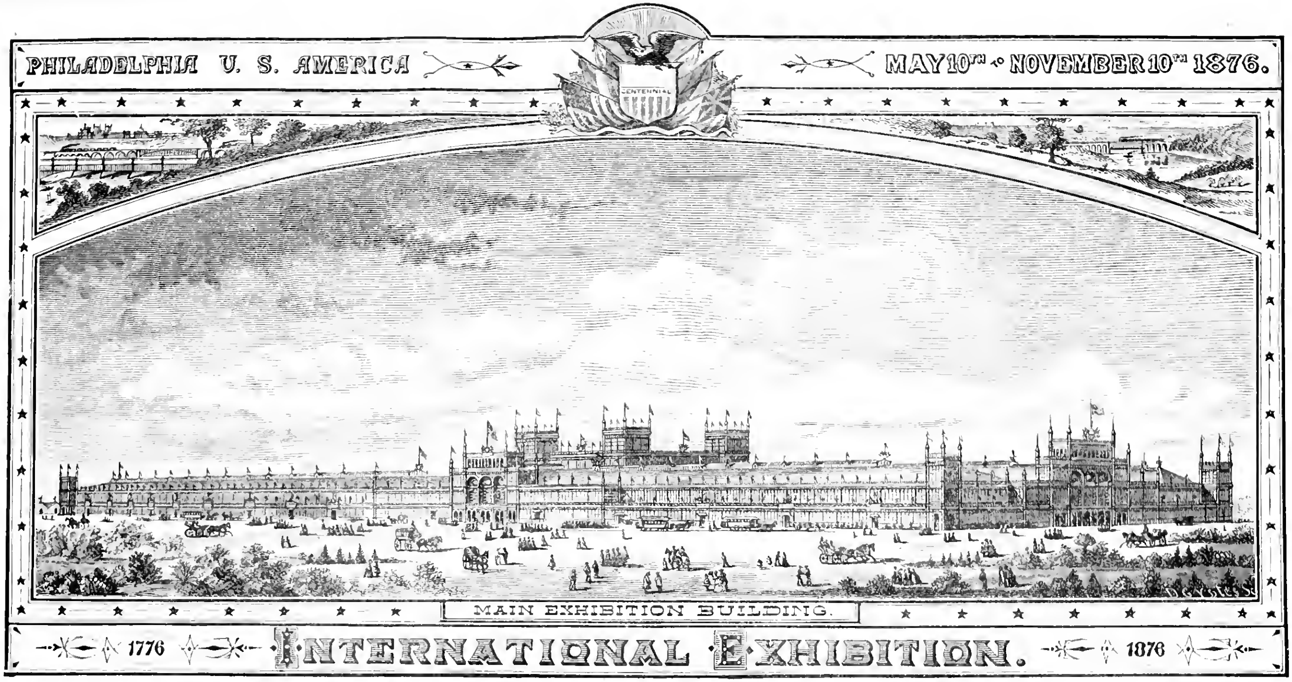
Centennial Exhibition.—The progress on the Centennial Buildings and Grounds, since our last issue, has been very marked and quite satisfactory to the building committee and to the commission, and the advanced stage of the preparations generally, as compared with those for the late European International Exhibition, has been very favorably commented on by several distinguished foreigners, who have had large opportunities for such comparison.

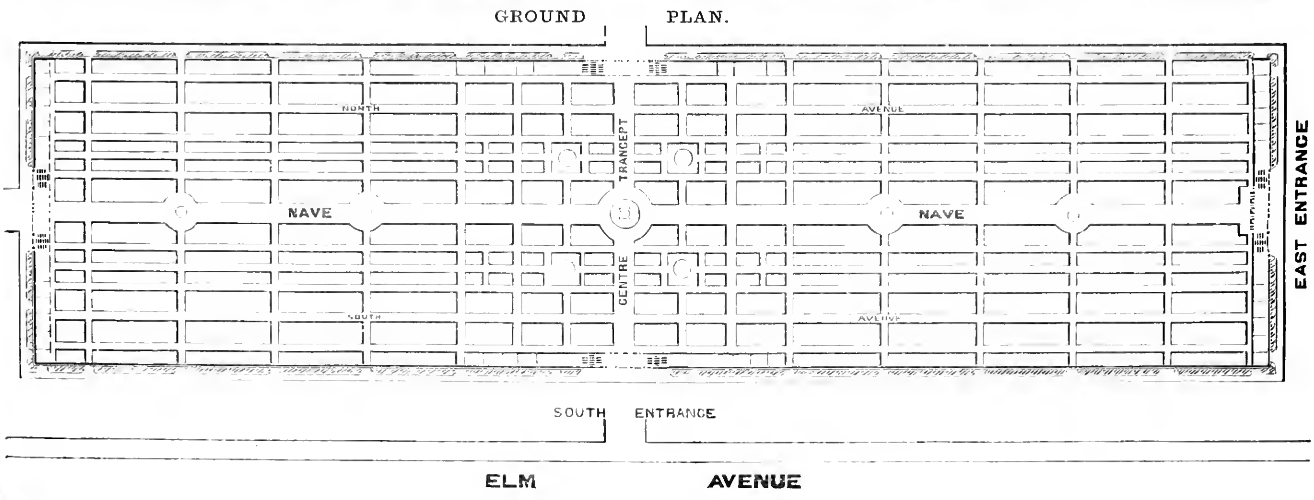
The Main Exhibition Building, of which we give illustrations is in the form of a parallelogram, extending east and west 1,880 feet in length, and north and south 464 feet in width. The larger portion of the structure is one story in height, and shows the main cornice upon the outside at 45 feet above the ground, the interior height being 70 feet. At the centre of the longer sides are projections 416 feet in length, and in the centre of the shorter sides or ends of the building are projections 216 feet in length. In these projections, in the centre of the four sides, are located the main entrances, which are provided with arcades upon the ground floor, and central façades extending to the height of 90 feet.

The East Entrance will form the principal approach for carriages, visitors being allowed to alight at the doors of the building under cover of the arcade. The South Entrance will be the principal approach from street cars, the ticket offices being located upon the line of Elm Avenue, with covered ways provided for entrance into the building itself. The Main Portal on the north side communicates directly with the Art Gallery, and the Main Portal on the west side gives the main passage way to the Machinery and Agricultural Halls.

Upon the corners of the building there are four towers, 75 feet in height, and between the towers and the central projections or entrances, there is a lower roof introduced showing a cornice at 24 feet above the ground. In order to obtain a central feature for the building as a whole, the roof over the central part, for 184 feet square, has been raised above the surrounding portion, and four towers, 48 feet


Agricultural Hall.
Horticultural Hall.
Memorial Hall or Art Gallery
Main Exhibition Building
Machinery Building.
1776
1876


PHILADELPHIA U. S. AMERICA
MAY 10TH to NOVEMBER 10TH 1876.
CENTENNIAL
MAIN EXHIBITION BUILDING.
1776
INTERNATIONAL EXHIBITION.
1876


GROUND PLAN.
NORTH
AVENUE
TRANCEPT
NAVE
NAVE
CENTRE
SOUTH
AVENUE
EAST ENTRANCE
SOUTH ENTRANCE
ELM AVENUE

Memorial Hall or Art Gallery.

square, rising to 120 feet in height, have been introduced at the corners of the elevated roof.

The areas covered are as follows:

Ground Floor,	872,320	square feet.	20·02 acres
Upper Floors in projections,	37,344	" "	·85 "
" " in towers,	26,344	" "	·60 "
	936,008		21·47

The general arrangement of the ground plan shows a central avenue or nave 120 feet in width, and extending 1,832 feet in length. This is the longest avenue of that width ever introduced into an Exhibition Building. On either side of this nave there is an avenue 100 feet by 1,832 feet in length. Between the nave and side avenues are aisles 48 feet wide, and on the outer sides of the building smaller aisles 24 feet in width. In order to break the great length of the roof lines, three cross avenues or transepts have been introduced of the same widths and the same relative positions to each other as the nave and avenues running lengthwise, viz; a central transept 120 feet in width by 416 feet in length, with one on either side of 100 feet by 416 feet, and aisles between of 48 feet. The intersections of these avenues and transepts in the central portion of the building result in dividing the ground floor into nine open spaces free from supporting columns, and covering in the aggregate an area of 416 feet square. Four of these spaces are 100 feet square, four 100 feet by 120 feet, and the central space or pavilion 120 feet square, The intersections of the 48 feet aisles produce four interior courts 48 feet square, one at each corner of the central space.

The main promenades through the nave and central transept, are each 30 feet in width, and those through the centre of the side avenues and transepts 15 feet each. All other walks are 10 feet wide, and lead at either end to exit doors.

The foundations consist of piers of masonry. The superstructure is composed of wrought iron columns which support wrought iron roof trusses. These columns are composed of rolled channel bars with plates riveted to the flanges. Lengthwise of the building the columns are spaced at the uniform distance apart of 24 feet. In the entire structure there are 672 columns, the shortest being 23 feet and the longest 125 feet in length. Their aggregate weight is 2,200,000 pounds. The roof trusses are similar in form to those in general use for Depots and Warehouses, and consist of straight rafters with struts

and tie-bars. The aggregate weight of iron in the roof trusses and girders is 5,000,000 pounds. This building being a temporary construction the columns and trusses are so designed that they may be easily taken down and erected again at another site. The sides of the building for the height of seven feet from the ground are finished with brickwork in pannels between the columns. Above the seven feet, with glazed sash. Portions of the sash are movable for ventilation. The roof covering is of tin upon sheathing boards. The ground flooring is of plank upon sills resting upon the ground, with no open space underneath. All the corners and angles of the building upon the exterior are accentuated by galvanized iron octagonal turrets which extend the full height of the building from the ground level to above the roof. These turrets at the corners of the towers are surmounted with flag staffs, at other places with the national eagle. The national standard with appropriate emblems is placed over the centre of each of the four main entrances. Over each of the side entrances is placed a trophy showing the national colors of the country occupying that part of the building, At the vestibules forming part of the four main entrances variegated brick and tile have been introduced. The building stands nearly due east and west and is lighted almost entirely by side light from the north and south sides. Louvre ventilators are introduced over the central nave and each of the avenues. Skylights are introduced over the central aisles. Small balconies, or galleries of observation, have been provided in the four central towers of the building at the heights of the different stories. These will form attractive places from which excellent views of the whole interior may be obtained. A complete system of water supply with ample provision of fire cocks, etc., is provided for protection against fire, and for sanitary purposes.

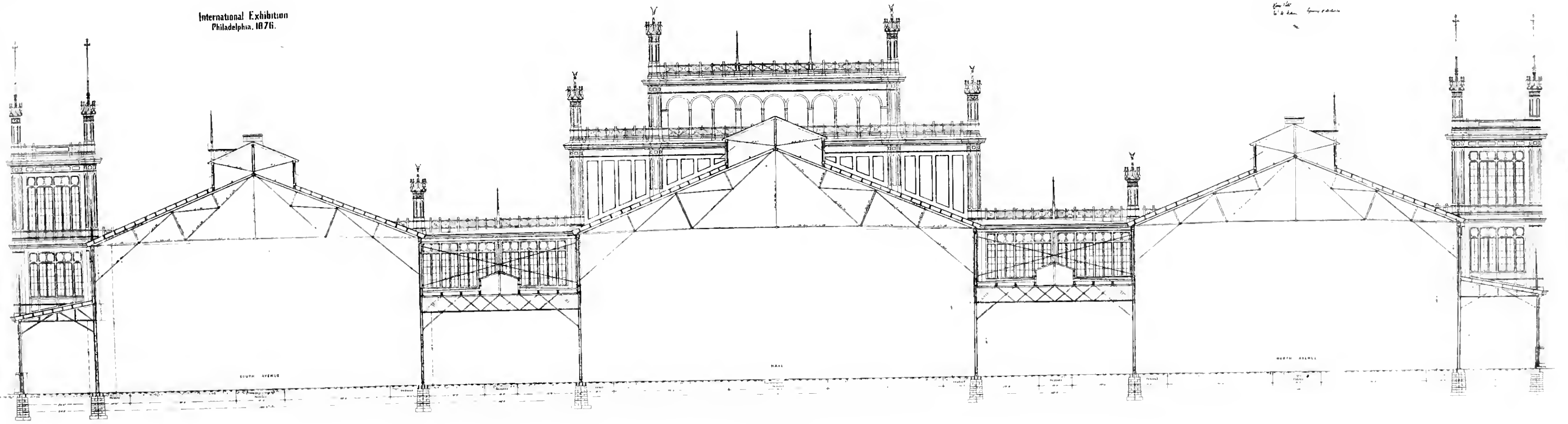
Offices for Foreign Commissions are placed along the sides of the building in the side aisles, in close proximity to the products exhibited. As many of the 24 feet spaces being partitioned off for that purpose as may be required. Offices for the administration may be placed at the ends of the building and on the second floor.

The form of the building is such that all exhibitors will have an equally fair opportunity to exhibit their goods to advantage. There is comparatively little choice of location necessary, as the light is uniformly distributed and each of the spaces devoted to products is located upon one of the main thoroughfares.

The erection of the main exhibition building is progressing very

International Exhibition
Philadelphia, 1876.

Main Exhibition Building



No 7
Section through Wings

satisfactorily, six or eight sections per week being added, at which rate the entire framework should be completed in August.

The setting of the granite on the south and east fronts of the Art Building is nearly completed, and on the other portions being well along. The roof is being placed on the eastern half, and the scaffolding for the erection of the dome is in place.

All the framework of that portion of Machinery Hall from its eastern end to the transept (nearly half) is up, and considerable of it is under roof, and is expected to be floored and so far finished that it will be used for the celebration of the 4th of July. Meanwhile the western half of the building is being erected with the same energy that has been so apparent since its commencement.

The Horticultural Hall has risen to the coping of the masonry, and is now receiving the iron framework of the superstructure. One of the Administration Offices, 100 by 80 feet, is so far completed that a portion is now occupied.

Ground will be broken for the Agricultural Building on the 5th of July next, and the arrangements for its erection are of such a character, as to insure its completion in ample time.

The designs for the Bridge across Landsdowne Valley are completed and the contract for its erection is executed. This bridge, which was originally intended to be a temporary one, it is now proposed to make a permanent structure. It will be 80 feet wide, and the line of the enclosure of the grounds will divide its width, leaving 50 feet outside for the park drive and 30 feet on the inside as a means of communication between the Art Building and Horticultural Hall.

A contract has been entered into with Mr. H. R. Worthington, of New York, for the erection of a compound duplex pumping engine of five to six millions gallons capacity, to supply the Exhibition with water. This will be located on the bank of the Schuylkill, on the north of Landsdowne Creek, and the water will be conducted thence up the valley to the system of distributing pipes in the various buildings and grounds.

The correspondence with foreign governments and commissions shows that active and extensive preparations are being made by nearly all of them for participating in our national celebration, and while there is no doubt that our own people have the matter very much at heart, it is well to consider whether we are sufficiently alive to the importance of beginning our preparations at once and of making early application for space. K.

Merriman's Water-proof Life Saving Dress has attracted much attention for a year past and has been subjected to very severe tests, which have fully confirmed the high opinion expressed in its favor last summer.

Its good qualities were fully developed by Capt. Boyton in his two trips across the English Channel, quite recently; and at the meeting of the Institute in April, a duplicate of the one used by him was exhibited.

The dress is composed of two principal parts: the upper portion consists of the shirt or jacket, a head piece, sleeves and gloves, all in one piece, and made of rubber-cloth or other water-proof material. The lower portion is composed of the pantaloons and boots in one piece of similar material. The front of the head piece, corresponding with the face of the wearer, is made highly elastic, and has an aperture of suitable size to expose the eyes, nose and mouth. The top, back and sides of the head piece are made double, forming a cavity for the purpose of admitting of expansion by inflation. The effect of this inflation is not only the support of the head when it rests upon the surface of the water, but it draws the elastic edges of the aperture tight around the face, preventing the ingress of water to the interior of the dress.

The back and front of the shirt are also double, the cavity in the back extending upward over the back of the neck to the head. The pantaloons are also double from the waist to the knees, forming cavities front and back for inflation.

All these cavities are provided with flexible tubes, long enough to reach the mouth of the wearer and have proper valves and stop-cocks. By means of these tubes the several parts of the dress may be inflated to any desired degree. At the upper edge of the pantaloons is fastened a rigid hoop, over which is stretched the lower edge of the shirt, and secured water-tight by means of a waist belt drawn firmly around all.

By dividing the dress in two parts, which can be readily joined in a water-tight manner, it can be put on and secured by the wearer in a very short time, and inflated without aid from others.

A great advantage of this dress, besides its floating power, is that the air cavities surrounding the vital portions of the body, protect it from becoming chilled by long exposure in the water. K.

Chemical Composition of Metaline.—We find a note upon this new dry lubricant in *Dingler's Polytechnisches Journal*, written by Vogdan Hoff. During his residence in London, he had considerable experience with it, and with the company manufacturing it. In order to reduce the friction to a minimum, the greatest care is necessary in working the surfaces which are to come in contact, so as to run perfectly true and to have a high polish. In the bearing holes are bored in series, two or three centimeters distant from each other, and three millimeters deep. These are then filled with metaline, which thus constitutes the sole lubricating material. The substance itself is a graphite-like mass only a little harder than lead. It does not melt on being heated, but evolves a tar-like odor. On cooling, it returns to its original consistence. Under the microscope, some of its constituents may be detected, namely, scales of graphite, metallic particles, and amorphous white grains. A specimen furnished by the metaline company, on being subjected to analysis, afforded the following composition :

Paraffin,	4·98.
Carbon,	18·89.
Silica,	6·44.
Lime,	3·96.
Magnesia,	1·99.
Ferric Oxide,	3·94.
Alumina,	2·53.
Lead,	32·40.
Zinc,	20·07.
Tin,	1·55.
Copper,	2·75.
Moisture,	0·51.
	100·01.

Tracing Paper.—M. C. Puscher has lately invented a very simple method of making and unmaking tracing paper, which promises to be of great service. The drawing paper to be made transparent is well moistened with a sponge wet with a solution of castor oil in two or three times its volume of absolute alcohol, according to the thickness of the paper. After a few minutes the alcohol evapo-

rates and leaves the paper ready for use. The drawing may now be made upon it either in crayon or in India ink. After this the paper is restored to its original opacity by immersing it for a given length of time into absolute alcohol, which dissolves and removes the oil. The alcohol so used serves for making a new solution.

Bibliographical Notices.

THE MICROSCOPE AND ITS REVELATIONS. By WILLIAM B. CARPENTER, M.D., L.L.D., etc. Fifth edition; illustrated by twenty-five plates and four hundred and forty-nine woodcuts. Small 8vo., pp. xxxii, 848. Philadelphia, 1875. (Lindsay & Blakiston.) The present treatise on the microscope has been long known as perhaps the best book in English upon the general subject. The high position of its author among physiologists, and his extensive acquaintance with the microscope in connection with his special studies, makes him abundantly competent in this direction. In the edition before us, the whole of the matter is stated to have been carefully revised. Many new forms of microscope and of microscopical appliances are now described for the first time, and some of the more important results of microscopical investigation have been introduced. For the American reader, however, it would have been desirable to mention some of the noteworthy stands and objectives made in this country, and to have given more space to the microscopic work done here. Mr. Tolles is the only manufacturer mentioned, and he only incidentally. Dr. Woodward's excellent work, especially in photography, and Dr. Wormley's in micro-chemistry are referred to, though not *in extenso.* Without raising the question here whether an entirely new book is not preferable to a new edition of quite an old one, we may still say that the beginner in microscopy will find this book of Dr. Carpenter's very useful for consultation; and that the advanced microscopist will find its well arranged pages of great service for ready reference. Of course, as in all cases of special study, monographs on the particular subject under investigation, can alone be expected to give minute microscopic details. The book before us is a fac-simile of the English edition, having been printed (and we suppose bound) on the other side of the ocean, for the American publishers, and with their imprint. The plates and woodcuts are excellent, and the general typography and binding are very creditable.

Franklin Institute.

HALL OF THE INSTITUTE, April 21st, 1875.

The stated meeting was called to order at 8 o'clock, P.M., the President, Dr. Robt. E. Rogers in the chair.

There were 92 members present.

The minutes of the stated meeting, held March 17th, were read and approved.

The Actuary presented the minutes of the Board of Managers, and stated that at the meeting held on the 14th inst., the following donations to the Library were received:

Geological Survey of Canada. Report of Progress for 1873–4. From A. R. C. Selwyn, F. R. S., &c.

Report of the Commissioner of Education for the year 1873. From the Commissioner. Washington.

Report of the Proceedings of the Conference on Maritime Meteorology, held in London, 1874. Protocols and Appendices. From the Meteorological Committee. London.

Fifth Annual Report of the Board of Commissioners of Public Charities of the State of Pennsylvania, 1874. From the Board of Public Charities.

The Secretary reported that the Board at its last meeting, considered the plans for the alteration of the Institute Building, submitted by the committee appointed for that purpose, and approved of that portion relating to the second floor, which contemplates removing one of the stair-cases and a portion of the partition between the Library Room and the Hall, thus utilizing about three-fifths of the latter for the use of the Library. The plans were then referred back to the committee for perfecting in detail, and to have embodied in them arrangements for heating and ventilation.

The Secretary presented the "Sansom" wheel jack, the invention of H. E. Nittinger, a convenient and compact instrument for raising and holding the axles of wagons and other vehicles, while the wheels are cleaned or removed. Also a specimen of an improved dioptric, or water light, the invention of M. C. Meigs, Quartermaster General U. S. A., for the use of students, mechanics, artists, and others who need a strong light, which shall at the same time be steady and soft.

The Secretary presented a statement showing an increasing demand for Engineering Instruments of Philadelphia make; Messrs. Heller & Brightly having recently received a large number of foreign and domestic orders which have heretofore been given to European manufacturers.

As a matter of interest connected with the coming Centennial, the Secretary projected on the screen a plan and elevation of a hotel to be 669 feet long by 204 feet wide, occupying the square of ground bounded by 39th and 40th, Poplar and Sylvan Streets. It is proposed to so construct the building that it may be easily converted into dwellings, such as are likely to be in demand in that section of the city after the exhibition is over.

The Secretary then presented a large number of views showing considerable advancement on the Centennial Buildings, also a plan of the situation of the different buildings, and other improvements in the Centennial grounds.

Mr. J. E. Mitchell offered the following amendment to the By-Laws:

Resolved, That Section 7 of Article 2 of the By-Laws be repealed.

In response to an inquiry, the chair made some further explanation of the proposed alterations to the building, and some discussion followed, participated in by Messrs. Close, Hoover, Lippman and Orr.

Mr. J. J. Weaver offered the following amendment to the By-Laws.

Article 5, Section 1 of By-Laws be amended by adding to the second sentence the following: "And, provided further, that no member of the Board of Managers shall be eligible for re-election as a Manager for the period of two years after his term of office has expired."

Article XVI, of By-Laws, be amended, by striking out the last sentence, and substituting the following: "In all cases, notice of proposed amendments shall be given in connection with the notice of meeting at which said amendment is to be acted upon, by publication daily in three or more newspapers, published in the city of Philadelphia, for at least three consecutive days immediately preceding the time of said meeting." These amendments were seconded by Mr. Chabot.

Mr. Close moved to postpone the advertising of all the proposed amendments for one month, which was carried.

On motion the meeting then adjourned.

J. B. Knight, *Secretary.*

Civil and Mechanical Engineering.

ON THE THEORY OF THE TENSION OF BELTS.

By Prof. L. G. Franck, of the University of Pennsylvania.

A few gentlemen practically engaged in mechanical engineering, who, as they state, have sufficient knowledge to follow a mathematical demonstration, requested me to advance a theory on the tension of belts on pulleys, for comparison with their own practical experience, and they further express the desire to have the theory published in one of the scientific periodicals.

Complying with their wishes, I have to make a few preliminary remarks, upon which the subsequent theory is based.

The friction* of the belt on the circumference of the driving pulley is, in my opinion, the force that drives the belt with the same circumferential velocity with which the pulley moves.

But as this is contrary to the views of many writers on mechanics, and as it is laid down in standard works that friction is but a negative force—that, in other words, friction can never be the source of motion—therefore it appears to me necessary to establish argumentatively the view above expressed.

If it were true that friction never can become a positive force, the uppermost doctrine in mechanics, namely, that action and re-action are equal to each other, would be radically destroyed. There are quite a number of examples which clearly show that friction is the source of motion. For if the motion of a body upon a support is to some degree resisted by friction, this same friction reacts upon the support equally, and will either move it or will have a tendency to do it. This is illustrated by the friction wheels, friction clutches, the jump-

* Some writers call this force adhesion; but as it will be shown in the sequel that this force is independent of the area or surface, it cannot properly be called adhesion, which we know is dependent on area.

ng back of a wedge-shaped key, and also by air passing over a surface of water, in consequence of which particles of the water are put in motion.

I shall now proceed to derive a few formulæ, and will illustrate them by numerical examples. In order not to involve too much mathematics, I shall set out with the well-known formula derived almost in every treatise on mechanics:

$$P = \left(1 + 2f \sin \frac{\alpha}{2}\right)^n Q. \qquad (1)$$

where P denotes the force required to start the weight Q; f, the coefficient of friction; α, the angle which two planes form; and n, the number of faces over which the belt passes. (Fig. 1.)

Fig. 1.

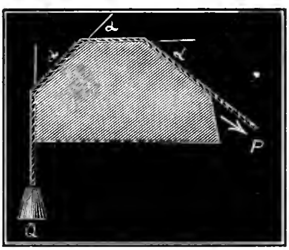
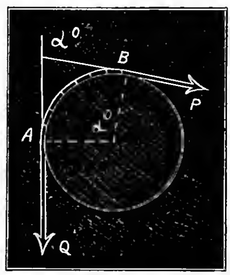


Fig. 2.



Now, fitting the above formula for a cylindrical surface—regarding the pulleys as cylinders—we must put α equal to the angle which two consecutive elements of a circle form. Since the number of elements is very great, the angle $\frac{\alpha}{n}$ is very small, and since the sine of a very small angle approximates its arc, we can put: (Fig. 2.)

$$P = \left(1 + 2f\frac{\alpha}{2n}\right)^n Q.$$

Raising this expression to the *n*th power, by means of the binomial theorem, and rejecting all terms after the second, as these quantities are not assignable, we obtain:

$$P = (1 + f\alpha)Q. \qquad (2)$$

where P and α are variable quantities, α denoting now any small portion of the circular arc AB, around which the belt stretches. If we

divide again the arc AB into elements and calculate the force P for the elements in succession, and add all these forces, we finally get the amount P to start the force or weight Q. This is shortest performed by calculus, as the subsequent derivation will show. From above we have:

$$P = Q + f\alpha Q; \text{ or } P - Q = f\alpha Q.$$

Now for the first element, near the origin A. Q is almost equal to P, wherefore we can put $P - Q = dP$,* and P instead of Q; we shall find then, putting for α its element $d\alpha$:

$$\frac{dP}{P} = f d\alpha.$$

Integrating between the limits A and B, we find:

$$\text{Log } P = f\alpha + C.$$

To determine the constant C, we have in the beginning $P = Q$ and $\alpha = 0$. Hence, $\log Q = 0 + C$. Therefore the whole expression becomes: $\text{Log } P - \log Q = \alpha f$, which gives:

$$\text{Log } \frac{P}{Q} = \alpha f, \text{ and } P = Qe^{\alpha f}. \qquad (3)$$

where e indicates the base of the Naperian system of logarithms = 2·718. We infer then from the above equation that if a weight Q attached to a flexible band (Fig. 2) is to be dragged around a fixed cylinder:

1. The force P is independent of the radius of the cylinder or pulley. That is to say, the amount of P remains the same whether the band, belt, or cord is wrapped say once about a cylinder whose diameter is one or ten feet.

2. The force P does not depend upon the width of the belt, as no algebraic symbol appears in equation (3) which expresses the width of the belt.

3. The force P depends on the pressure or tightening, (Q.)

4. The force P depends on the arc of contact between the belt and the smaller pulley, (α.) (Fig. 2.)

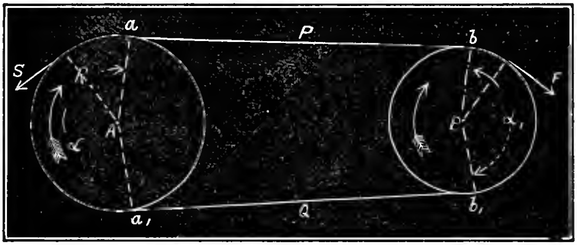
5. The force P depends on the coefficient of friction between the belt and surface of the pulley, (f.)

The value e remains constant under all circumstances. Now if we pass from the fixed pulley to two movable pulleys, turning around

* Differential of P.

their axes A and B, by means of a belt b a, a_1 b_1, that is put in motion by the driving pulley B (Fig. 3), transmitting its motion to the fol-

Fig. 3.



lower A, we have for the moment of resistance offered by the follower A, the product of the circumferential force and its lever-arm R, that is:

$$M = SR. \qquad S = \frac{M}{R}. \qquad (4)$$

In order that the belt shall not slip, the friction F on B must be equal to the force S (for equilibrium).

Now as the force P (tension of belt b a) has to overcome both the friction and the resistance (weight Q), the friction itself must therefore be equal to $F = S = P - Q$.

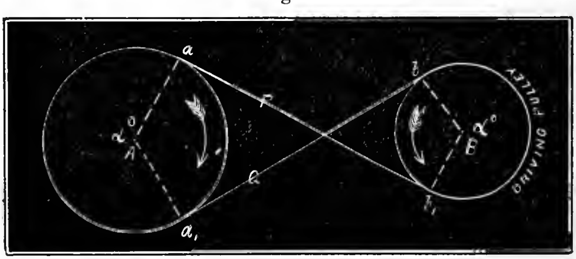
Hence if we subtract Q from the second member of equation (3) we obtain:

$$F = Q(e^{\alpha f} - 1). \qquad (5)$$

The arc α must be taken on the smaller pulley, as this gives the least value; and as F is independent of the radius, the arc is in all cases to be calculated for radius $= 1$.

While for pulleys with an open belt the angle is least at the smaller pulley (Fig. 3), the angle is the same no matter what size the pulleys have when the two branches of the belt cross each other (Fig. 4.)

Fig. 4.



Now to derive the expressions for the tension of the advancing belt a b, and the retiring belt $b_1 a_1$, (Fig. 3), we find when we put for $F = P - Q$, $P - Q = Q(e^{af} - 1)$, and as $Q = P - S$ from above, the expressions:

$$P = \frac{e^{af}}{e^{af} - 1} S, \qquad \text{and} \qquad Q = \frac{S}{e^{af} - 1}. \tag{6}$$

It appears then, from the inspection of the two last formulæ, that the greater we make the product of af, the less the tension P becomes. This I shall illustrate by two numerical examples.

Example 1. Required the tension of the advancing belt, when the two pulleys are equal in size and the coefficient of friction between leather belts and cast-iron pulleys is taken 0·25 on an average.

Here $a = \pi =$ half circumference $= 3{\cdot}14.$ . . . Hence

$$P = \frac{2{\cdot}718^{3.14 \times 0.25}}{2{\cdot}718^{3.14 \times 0.25} - 1} S = \frac{2{\cdot}718^{0.785}}{2{\cdot}718^{0.785} - 1} S = 1{\cdot}84 S.$$

Example 2. Required the tension of the advancing belt, when only four-tenths of the circumference of the smaller pulley is covered, f to remain 0·25.

$$P = \frac{e^{af}}{e^{af} - 1} S = \frac{2{\cdot}718^{6.28 \times 0.4 \times 0{\cdot}25}}{2{\cdot}718^{7.28 \times 0.4 \times 0.25} - 1} S = \frac{2{\cdot}718^{0.628}}{2\ 718^{0.628} - 1} S$$

$$P = 2{\cdot}14 S\ (7), \qquad \text{and} \qquad Q = \frac{S}{2{\cdot}718^{0.628} - 1} = 1{\cdot}14 S. \tag{8}$$

These theoretical values show that the advancing belt in the first example will be stretched by 1·84S, and in the second by 2·14S. But as in practical application it is impossible to get the exact value that is furnished by the theory, and as we have not brought into the calculation the stiffness of the belt nor the axle friction, we have to increase somewhat these theoretical values. Following here Reauleaux' advice, we add 0·26S. which will give us in the second example,

$$P = 2{\cdot}4 S\ (7), \text{ and } Q = 1{\cdot}4 S. \quad (8.)$$

The arithmetical mean of both values $P_0 = \frac{2{\cdot}4 + 1{\cdot}4}{2} S = 1{\cdot}9 S$, expresses then the amount of tension that should be given to the belt before motion takes place.

For cast-iron pulleys with open leather belts of about three-sixteenths of an inch thickness, the above two formulæ (7) and (8), provided that one of the pulleys is not very small comparatively, may be applied generally.

TO DETERMINE THE WIDTH OF THE BELT.

The tension of the belt is counteracted by the cross-section of the belt, that is $2{\cdot}4S = wtK$, where w denotes the width of the belt, t the thickness, both given in inches, and K the number of pounds which one square inch of belt will fairly resist, found by experiment. From equation (5) we have $S = \frac{M}{R}$ introduced into the above equation and solved with respect to w, we find $w = \frac{2{\cdot}4M}{tKR}$. (9)

In general M is not directly known, but the number of horse powers the pulley shall transmit is given, and the number of revolutions per minute of the pulley, or the number of feet that the belt travels per minute. From these data we are enabled to express S. Putting formula (9) in the form

$$w = \frac{2{\cdot}4S}{tK}, \qquad (10)$$

the dynamical effect of S for n revolutions in one minute is expressed. Number of horse powers $= N = \frac{2\pi RSn}{33000}$, from which we get $S = \frac{33000N}{2\pi Rn}$, which when introduced into equation (10) gives $w = \frac{2.4 \times 33000N}{2\pi RntK}$ where w denotes the width of the belt in inches, N the number of horse powers, R the radius in feet, n the number of revolutions, t the thickness of the belt, and K the resistance expressed in pounds which one square inch of belt can fairly counteract. Taking t = 3-16 inches, and for K, after Morin, 275 pounds. K depends on the quality of the leather, and ranges from 275 to 550 pounds per square inch. 275 pounds are recommended, however, by good authorities. Applying the latter we shall find, after reducing

the above numerical values, $w = \frac{250N}{nR}$, (11)

where the numerical value is rounded off to an even number.

Example 1.* A pulley of $1\frac{1}{2}$ feet radius makes 80 revolutions per minute, having to transmit one horse power. What should be the width of the belt?

Here $N = 1$; $n = 80$, and $R = 1\frac{1}{2}$.

$$\text{Hence } w = \frac{250}{80 \times 3\text{-}2} = \frac{25}{12} = 2\ 1\text{-}12 \text{ inches.}$$

Example 2. A pulley of 3 inches radius makes 900 revolutions per minute, and has to transmit 2 horse powers. What should be the width of the belt?

$$N = 2;\quad n = 900;\quad R = \tfrac{1}{4} \text{ ft.} \qquad w = \frac{250 \times 2}{900 \times \frac{1}{4}} = 2\ 2\text{-}9 \text{ inches.}$$

Solving equation (11) with respect to N, we find:

$$N = \frac{wnR}{250}. \tag{12}$$

Giving to w the exceptional width of 6 inches for a single belt, and assuming $n = 100$ revolutions per minute, and further the radius of the pulley $R = 1$ foot, we find the number of horse powers:

$$N = \frac{6 \times 100 \times 1}{250} = \frac{60}{25} = 2{\cdot}4 \text{ horse powers.}$$

The number of horse powers that are obtained is comparatively small, and it indicates that with pulleys and belts we cannot produce a very great effect unless we make the radius of the pulley very great, and apply an exceptionally great speed.

I should mention that the above formulæ refer to pulleys with open belts only, and that it is of no consequence whether the radius and respective number of revolutions are taken from the greater or

* As great nicety is not required in these calculations, the coefficient of friction may be taken in general as 0·25, and the arc covered by the belt as three-tenths of the circumference of the smaller pulley.

smaller pulley, as the numbers of revolutions are in an inverse ratio to the radii of the pulleys. That is,

$$\frac{R}{R_1} = \frac{n_1}{n}. \quad \text{Hence } Rn = R_1n_1.$$

If the belt is made up of two layers or thicknesses, so that such a belt of the same width as a single one contains the double cross section, we still may apply the upper formula, if we multiply it by $\frac{2}{3}$, owing to the greater stiffness of the belt.

Example. In order to transmit 4 horse powers, we have a pulley 1 ft. 8 in. by 120 revolutions per minute. What should be the width of the belt?

$$N = 4; \; R = 1\tfrac{2}{3} \text{ ft.}; \; n = 120.$$

$$w = \frac{2}{3}\,\frac{250N}{nR} = \frac{2}{3}\,\frac{250 \times 4}{120 \times 5\text{-}3} = 3\tfrac{1}{3} \text{ inches.}$$

For the single belt we should have received:

$$w = 3\text{-}2 \times 3\tfrac{1}{3} = 5 \text{ inches.}$$

COMPOUND AND NON-COMPOUND ENGINES, STEAM-JACKETS, ETC.

By Charles E. Emery, C. E., New York.

(Continued from Vol. lxix, page 277.)

(4 C.) It should be here observed that in the above comparison of the results of experiments with the steamer Bache and of the revenue steamers, the former shows more inferiority than can be attributed simply to the difference in size, and we are of the opinion that it was due somewhat to the quality of the steam furnished by the boilers. The boiler of the Bache was constructed to give a high evaporation, and the combustion was so slow that the steam in the steam-chimney received practically little heat from the escaping gases. On the revenue steamers, the boilers were made to develop the maximum power for a given space—the tubes were shorter, the draft freer, and the experiments being tried at maximum power, the gases passed through the steam chimney at a higher temperature than on the Bache, so that

the steam was more thoroughly dried. It appears incidentally, then, that a boiler with a less evaporative power than another, may, within certain limits, furnish steam of a better quality, and thereby produce increased economy in the engine. This is not fully demonstrated by these experiments, as both the size of the engines and the proportions of the boilers are different in the two series, but that there is some such compensation appears probable.*

In these experiments, however, the higher evaporation in the boiler of the Bache, more than compensated for the loss of efficiency in the engine, the best results with the compound engine of the Bache and that of the Rush being as follows:

	Bache.		Rush.	
	Table No. 1, Exp. 6.		Table No. 2, Exp. 1.	
Water actually used per I. H. P., per hour.	(line 46)	20·332	(line 53)	18·384
Water actually evaporated per pd. of coal.	(line 53)	9·131	(line 63)	7·549
Coal consumed per I. H. P., per hour.	(line 49)	2·227	(line 57)	2·435

The presentation shows that while there may be an interesting subject (which we shall investigate further), as to the compensation attainable in the engine by utilizing the waste heat of a boiler with low evaporative power, the higher evaporation will probably, as in this case, prove the better practically. Referring to Table 2, Exp. 1, line 70, it will be seen that with an evaporation of ten pounds of water per pound of coal, (a result attainable under the conditions named), one horse-power, would have cost but 1·838 pounds of coal per hour.

5. Economy of Steam as Influenced by the Steam Pressures employed.—The investigations with which we have been associated show invariably that, other things being equal, the higher the steam pressure the greater the economy. The saving, however, decreases rapidly, using ordinary engines, after a pressure of eighty pounds per square inch is reached, so much in fact that it is doubtful if pressures in excess of one hundred pounds would give a sufficient economy of

*It is to be regretted that the quality of the steam was not tested in all the experiments by means of a calorimeter. The writer, previous to the trial of the Bache, developed and put in practice a very simple apparatus for the purpose, but it was thought that there was so much to be done in a limited time, that the solution of the more important problems could only be attempted.

fuel to counter-balance the extra expense in constructing and maintaining the boilers. We have little information as to what can be done at pressures above one hundred pounds, with engines particularly designed for the purpose, and it is probable that a saving of space occupied by the machinery might in some cases warrant the use of very high pressures even with ordinary engines. Within the limits of common practice, the saving by the use of the higher pressures is very important, and some valuable information on the subject may be obtained from the experiments under discussion. We first examine the results due to using different steam pressures in the same cylinder.

(5 A.) With the non-compound engine of the Dexter, we find (Table No. 2, line 76) comparing experiments 3 and 7, which show the minimum cost at the approximate steam pressures respectively of 70 and 40 pounds, that the power at latter pressure cost 20·73 per cent. more than at the former. This is at about the same degree of expansion, and therefore doing less work, with the less pressure. Were it necessary to do the same work, in the same cylinder, as is the case in practice, comparing runs 3 and 9, we find the power would cost 33·24 per cent. more.

(5 B.) Experiments 13 and 17 on the Bache (Table 1), made at the steam pressures of 78 and 31 pounds, respectively, show a cost for the latter 29·6 per cent. greater than for the former.

(5 C.) In the case of the compound engine of the Rush (experiments 1 and 2, Table 2), made with the steam pressures of 69 and 37 pounds, respectively, the cost of the power at latter pressure is 20·18 per cent. greater than in the former.

(5 D.) The results due to working steam of different pressures in engines properly proportioned to give the maximum economy for the pressure used, involves questions discussed in the next title. Referring, however, to the results shown above, (5 A) and (5 B), it may be observed that if the lower pressure of steam is to be used, it can better be done in a cylinder proportioned as above indicated, and such was very nearly the case in the Dallas. Comparing experiments 11 and 3 (Table No. 2), where the power is nearly the same, we find (line 76) that the power in the low pressure engines of the Dallas cost 13·01 per cent. more than in the high pressure condensing engine of the Dexter.

(5 E.) Above are shown, (5 A), (5 B) and (5 C) practical comparisons of the results due to reducing the steam pressure in the same engine, which furnish a basis whereby we may account for the fact that compound engines in practical use show larger relative economies, compared with simple engines, than we have ascertained by experiment. In high pressure condensing engines, the pressure for various reasons is seldom maintained regularly at the point designed. This occurs from two causes, viz., carelessness of the operating engineer and the improper adaptation, by the designing engineer, of the size of the engine to the work it has to do. The latter, when true, as is too often the case, partially excuses the fault of the former, which subject is discussed in the next title. It is also true that no matter for what pressure the engine is designed, if it be intended to be operated with considerable expansion, the engineer soon finds that his engine works smoother with a lower pressure and less expansion, and naturally thinking, as is too often the case, that his duties are sufficiently arduous, lets his pressure fall or partially closes his throttle-valve and lengthens the cut-off for the most trivial excuses, until finally, notwithstanding his education and instructions, he really believes that it is exactly as well to work that way all the time.

The general prejudice against high pressure is in his favor, and it is not uncommon to have somebody on the vessel boast that their engineer can run with less pressure than somebody else, which is accepted as a matter to be proud of instead of being worthy of condemnation. To be sure, the expense account for coal increases somewhat, but it is attributed to the falling off due to continued service. If protestations of owners that something is wrong are repeated, and direct orders given to work more expansively, the result generally proves a failure; sometimes through lack of interest, and numerous complaints about leaky boilers, &c., and at other times trials are made of higher pressures when the engine really has got out of order and no saving can be observed. It is a fact that if the pistons have become leaky, it is as economical to use a lower steam pressure as a high one. The true remedy in such case is to refit the pistons and carry the pressure designed. We have of late, by the use of special arrangements, found no difficulty in keeping pistons continuously tight at any pressure.

(5 F.) With the compound engine, however, there are fewer mechanical difficulties in working high steam, and in most cases it is

TITLE.		Numper of experiments.	Ratio of expansion.	Mean effective pressure.	Cost in water per horse power per hour.		Number of experiments.	Ratio of expansi'n	Mean effective pressure.	Cost in water per horse power per hour.
Table 6 A.		Line 1.	Line 7.	Line 25.	Line 46.		Line 1.	Line 7.	Line 25.	Line 45.
Abstract from general table No. 1, U. S. Coast Survey steamer Bache, non-compound engine, approximate steam pressure 80 pounds.	With steam jacket in use on larger cylinder.	14	12.62	23.449	27.113	Without using steam jacket.	11	11 82	21.643	35.075
		15	8.57	27.54	24.088		12	7.62	27.273	29 616
		16	5.11	36.94	23.154		13	5.32	32.328	26.247
Table 6 B.		Line 10.	Line 17.	Line 36.	Line 53.		Line 10	Line 17.	Line 36.	Line 53.
Abstract from general table No. 2, U.S. Revenue Steamer Dexter, non-compound engine, approximate steam pressure 70 pounds.	....	3	4.46	34.439	23.857		5	3.49	37.538	23.905
	....	4	3.67	37.127	24.120		6	2.72	42.028	24.313
Table 6 C.		Line 10.	Line 17.	Line 36.	Line 53.	U. S. Revenue Steamer Dallas, engine non-compound, approximate steam pressure 35 pounds.	Line 10.	Line 17.	Line 36.	Line 53.
Abstract from general table No. 2.	U. S. Revenue steamer Dexter, (engine non-compound) approximate steam pressure 40 lbs.	7	3.34	25.583	28.802		10	5.07	18.522	26.687
		8	2.42	30.665	28.936		11	3.89	21.447	26.96
		9	2.08	33.838	31.786		13	2.94	24.611	28.901
Table 6 D.		Line 1.	Line 7.	Line 25*	Line 46.		Line 1.	Line 7.	Line 25.	Line 46.
Abstract from general table No. 1, U. S. Coast Survey Steamer Bache, compound engine, approximate steam pressure 80 pounds.	With steam jacket in use on larger cylinder.	4	16.85	20.379	25.108	Without using steam jacket.	1	9.146	22.421	23.765
		5	9.19	27.524	20.713		2	6.658	27.599	23.036
		6	6.97	31.843	20.332		3	5.634	29.781	23.210
		7	5.73	33.484	20.365		...	......	......	......
		10	4.24	36.940	21.169		...	......	......	......

* Mean effective pressure referred to larger cylinder.

difficult to keep up the speed with low steam. For instance, examining experiments 1 and 2 with the compound engine of the steamer Rush, it will be seen (Table 2, line 39) that the power at the lower pressure is much less than with the higher (168·6 to 266·5), so the engineer with an engine of proper size, would be obliged to increase the pressure to obtain sufficient power to propel his vessel at the speed designed. The result is that the average pressure carried for compound engines, even by careless engineers, is much higher than in single cylinder engines, and increased economy due to the steam pressure is obtained, independent of that due to the difference in engines, and we may expect to find in practice, as is commonly reported, that a compound engine operates with a saving of 20 to 25 per cent. compared with single engines using the same pressure, and that even more saving may be obtained when the single engine is greatly too large for its work, as hereinafter discussed.

6. The most economical Point of Cut-off for the Pressure employed.—When it is desired to obtain a given power, using steam of a given pressure, fixing the point of cut-off fixes also the mean pressure in the cylinder, and for a given speed of revolution, the size also of the cylinder required. Our experimental researches show that the most economical grade of expansion varies for every steam pressure, and is influenced somewhat by other conditions.

The preceding tables have been condensed from the general tables, and show the mean pressures and costs of the power at different degrees of expansion for the engines of the several steamers.

Referring to Table 6 A, it will be seen that, with the engine of the Bache, operated non-compound, using an approximate steam pressure of 80 pounds, expanded 5·11 to 12·62 times, the higher grades of expansion were attended with positive loss, and by reference to Table 6 B it will be seen that, with the single engine of the Dexter, using an approximate steam pressure of 70 pounds, expanded 2·72 to 4·46 times, there was but little difference in economy between an expansion of 3·49 times and one of 4·46 times. We may, therefore, infer that an expansion of five times, under the conditions of these trials, using 80 pounds of steam, in single engines, is as much as can be obtained economically, and that the expansion should be somewhat reduced for a pressure of 70 pounds.

Referring to Table 6 C, it will be seen that, with the single engine of the Dexter, using an approximate steam pressure of 40 pounds ex-

panded 2·08 to 3·34 times, (the latter expansion is the more economical) and that, with the engine of the Dallas, using an approximate steam pressure of 35 pounds, expanded 2·94 to 5·07 times, no loss, but rather a slight gain in cost of indicated power, is shown at an expansion of 5·07 times, as compared with that at 3·89 times—this engine operating, as before stated, very economically at the pressure used. The results at the two expansions last named are, however, so nearly identical, that the cost for the net power (see Table No. 2) is least for the least expansion; considering the experiments on the Dexter and Dallas together, we may conclude that an expansion of $3\frac{1}{2}$ to 4 times is the most economical degree for steam pressures of 35 to 40 pounds.

Referring to Table 6 D, it will be seen that, even with the compound engine of the Bache, operated with an approximate steam pressure of 80 pounds, expanded 4.24 to 16.85 times, a loss resulted at the extreme degree of expansion, and that an expansion of 6 to 7 times appeared to give the best results under the conditions of the trials.

It is not practicable, with the information available (many experiments not having been put in shape for comparison), to calculate accurately the proper rates of expansion for different steam pressures, and it is probable that no fixed rule could be framed to include the modifications due to all conditions. We give the following provisional rule, with tabulated examples:

(6 E.) RULE.—To the number representing the steam pressure above the atmosphere (P) add 37; divide the sum by 22; the quotient will represent, approximately, the proper ratio of expansion (R) for that steam pressure. That is

$$R = \frac{(P+37)}{22}$$

EXAMPLES:

Steam pressure above atmosphere $= P$	5	10	25	40	60	80	100
Ratio of expansion $= R$	1·9	2·1	2·8	3·5	4·4	5·3	6·2

It is probable that these ratios are nearly correct for single engines of large size with details of good design, too large for single engines of ordinary construction, and too small for the better class of compound engines. The rule, though provisional, is safer to follow than the uncertainties of personal opinion, and the variations of actual

practice. Further information cannot vary it materially, for the economy changes very little for expansions considerably greater or less than the most economical grade. The limit of expansion for the higher pressures are apparently well defined by the experiments discussed, but there are indications that there is no loss in using somewhat higher expansions than given by rule for steam pressures of 35 to 40 pounds—of course, however, with results inferior to those obtained by using higher pressures. Further investigations are being made on this subject.

(6 F.) As a general rule, in constructing an expansive engine, too much expansion is attempted and the cylinder is made much too large for the work to be done. This is particularly true in respect to engines designed to be operated expansively with high steam pressures. As previously referred to, the designing engineer, in almost every instance, furnishes too much cylinder to work off the steam from a given boiler at the most economical degree of expansion for the pressure intended. This is one of the most important lessons to be learned from these experiments, and many others as yet unpublished. Nearly all the marine engines constructed have cylinders of sufficient size to develop the power intended with a mean pressure of 25 to 20 pounds, and even lower. These experiments show clearly that it is not economical to expand high pressure steam sufficiently to produce so low a mean pressure, and that with such large cylinders it would be nearly, if not quite as well, to reduce the steam pressure and expansion (as we have complained previously, that the working engineers are in the habit of doing, though to an unwarranted extent). The best results shown by these experiments were obtained with a mean pressure of 34 to 37 pounds, when the boiler pressures were from 70 to 80 pounds, and, therefore, the steam cylinders of non-compound high pressure condensing engines should be not more than two-thirds the size they are usually made. Engines so proportioned would not only work with greater economy, but also with less expansion than those with larger cylinders, so that there would be a more equable pressure throughout the stroke when high steam was used, and less trouble to the engineer. Such an engine, properly constructed and operated, would probably require but about 15 per cent. more fuel than the best form of compound engine to do the same work.

(6 G.) We are now constructing a non-compound high pressure condensing engine, which is fitted with expansive gear, adjustable

only between one-sixth and one-fourth the stroke. To manœuvre the vessel, the cut-off must be thrown entirely out of gear, and distribution of steam effected entirely with main valve. It is hoped that the arrangement will prevent the temptation to reduced expansion, which would take place to an important extent, even when using a cylinder of proper size for the work to be done.

Indicator Diagrams.—Annexed will be found specimens of the indicator diagrams taken during the principal runs. Diagrams for each series of experiments on the Bache have been selected with like steam pressures and traced together for facility of comparison.

Hyperbolic curves have been dotted upon one series of the diagrams in such manner as to coincide with the experimental curves near the points of suppression. When the diagrams were taken, the indicators were carefully adjusted so as to be perfectly free in their action, and in some of the diagrams vibrations of the pencil may be observed at the points of cut-off outside the true experimental lines.

The diagrams considered together show a number of differences due to the various changes of condition. As stated previously, the steam supplied by the boilers of the revenue cutters was probably superheated slightly, and the expansion curves on diagrams *F*, *G*, *H*, from their engines more nearly correspond with the Mariotte curves of expansion than the majority of those from the engine of the Bache. The boiler of the Bache was operated much below its power when furnishing steam at the high grades of expansion used (see 4 C), and as the steam room was large, the water level very steady, and extra precautions had been taken to felt the boiler, steam-pipe and valves, the steam supply must have been delivered to the engine in about the same condition as if from a boiler without any superheating surface, or say very nearly saturated or containing but a slight percentage of moisture. The diagrams show, however, that liquefaction rapidly took place when the walls of the cylinder were alternately cooled and reheated as described above, (3 C). When using the single cylinder of the Bache without steam-jacket (see diagram *B*), the expansion curve for bottom of cylinder fell below the Mariotte curve at first, but afterwards rose above it as re-evaporation took place. In the top of the cylinder, however, some water collected, and its re-evaporation during the expansion portion of the stroke caused the expansion curve to rise above the Mariotte curve at all times. At the highest grade of expansion, with and without use of jacket, a loop was found on the dia-

gram from the upper end of the cylinder in two instances (as shown in diagrams *C*), which disappeared upon opening the cylinder relief valve.

These diagrams show that horizontal engines should be more economical than vertical ones, for the reason that when properly constructed, the cylinder can be kept drained at all times.

When using the single cylinder of the Bache, with jacket (see diagrams *A*), the moisture in the steam due to reheating the surfaces was re-evaporated throughout the stroke, causing the expansion curve to rise above the Mariotte curve in most cases. As before, the difference is greater for the top of the cylinder and very large for the shortest suppressions.

With the compound engine of the Bache, the expansion curve for the smaller cylinder which was not steam-jacketed (see high pressure diagrams *D*), also rises materially above the Mariotte curve. The cut-off valve faces were in excellent condition, making leaks improbable, so the difference is doubtless due also to re-evaporation of moisture. The exhaust from the smaller cylinder of compound engine is not so effective in carrying moisture out of the cylinder as in ordinary engines with less back pressure. The slight superheating of the steam on the Rush, together with the steam-jacket, was sufficient to prevent great variation of the two curves (see high pressure diagram *F*).

When the engine of the Bache was operated as a compound engine, without the jacket on the larger cylinder, there was a material reduction of pressure in that cylinder throughout the stroke, as compared with that during the experiments with steam-jackets in use, which may be observed by comparing low pressure diagrams *D* and *E*, and the mean pressures shown in line 25 of Table No. 1.

Superheating.—In conclusion it may be observed that the diagrams taken at the higher grades of expansion on the Bache show such positive evidence of the presence of water in the cylinder (due doubtless, as has been stated, to internal condensation), that it may be claimed that by superheating the steam, the ratio of expansion could be economically increased beyond that shown by the Bache experiments. In discussing this question, however (subject 6), the conclusions were founded on the experiments both with the Bache, where there was probably no superheating, and with the cutters where the

conditions were favorable for the thorough drying of the steam. From both series, and other experiments available, it is concluded that superheating will undoubtedly reduce the final cost, but it does not appear that it will change in a material degree the most economical point of cut-off for a given steam pressure. Superheating should, in fact, show beneficially in the same way as the steam-jacket and in a measure reduce the advantages shown by the latter.

The variations above referrred to between the actual and Mariotte expansion curves, which show, doubtless, the presence of extreme internal condensation, are frequently observed in marine engines using high grades of expansion, and in such cases we may naturally infer, from the whole evidence presented, that there is also a loss of result compared with that obtainable with less expansion. In the experiments with the single cylinder of the Bache, it may be noticed, incidentally, that the expansion curves on diagrams from the bottom of the cylinder correspond closely with the Mariotte curves (particularly with steam-jacket in use), when the engine is working at its most economical grade of expansion, and we have observed a similar correspondence in diagrams from both ends of the cylinder of horizontal engines, where provision was made to drain the water from the cylinder at each stroke.

The Mariotte curve has been used for comparison simply for convenience, without discussing the question whether it is the true expansion curve or not.

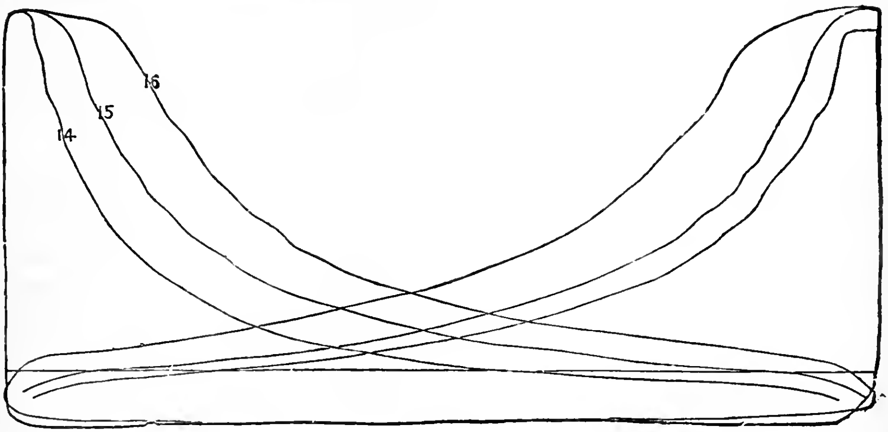
Artificial Hardening of Sandstone.—Manfred Lewin has tried with success in his quarries at Saxonia, and at Neundorf, near Pirna, a process of impregnating sandstone. The stone there quarried is porous and readily absorbs water to a certain depth; it is this fact which renders it possible to introduce a solution to harden the surface. Lewin impregnates the stone with solutions of an alkaline silicate and of alumina; there is thus formed an aluminum silicate within its pores, which gives to the surface considerable resistance. The solutions employed are made with soluble glass and with aluminum sulphate. After the impregnation, the sandstone may be polished like marble, which it then resembles closely. Heated to a high temperature, the exterior layer vitrifies and thus may be colored at pleasure. The coloration may even be obtained simply by mixing the desired pigment with one of the two solutions used for the impregnation.

INDICATOR DIAGRAMS.

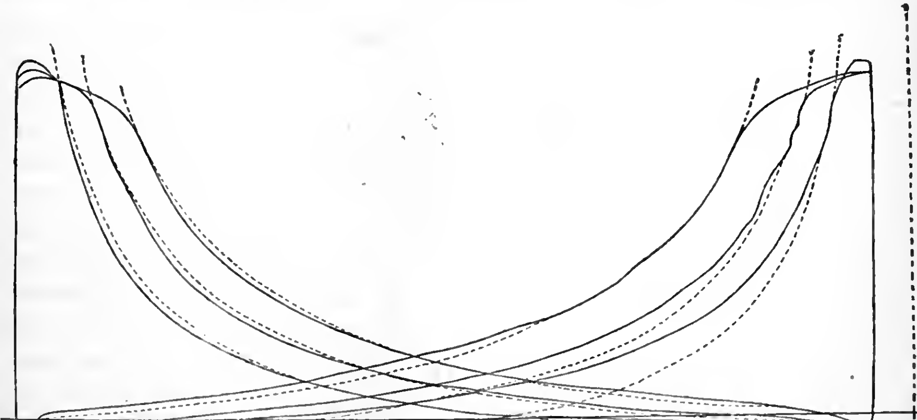
U. S. Coast Survey Steamer "Bache."

The numerals on the diagrams refer to the number of the experiment in Table No. I.

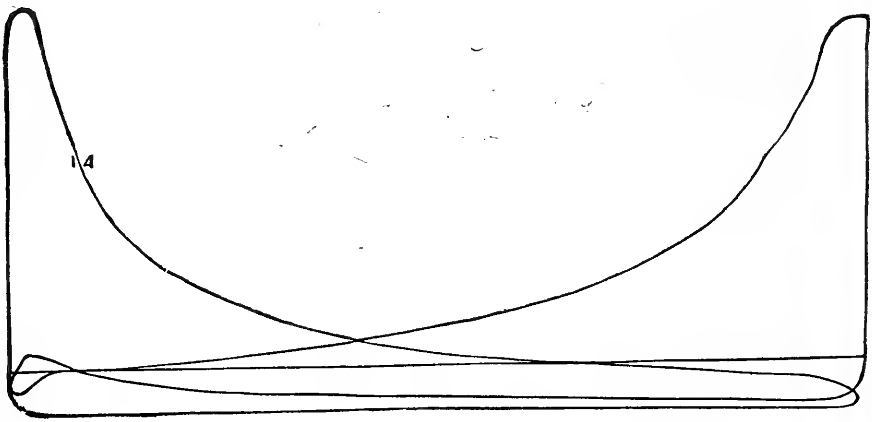
A.—STEAMER "BACHE." SINGLE ENGINE, USING STEAM JACKET. INDICATOR SCALE, 40 LBS. PER INCH.



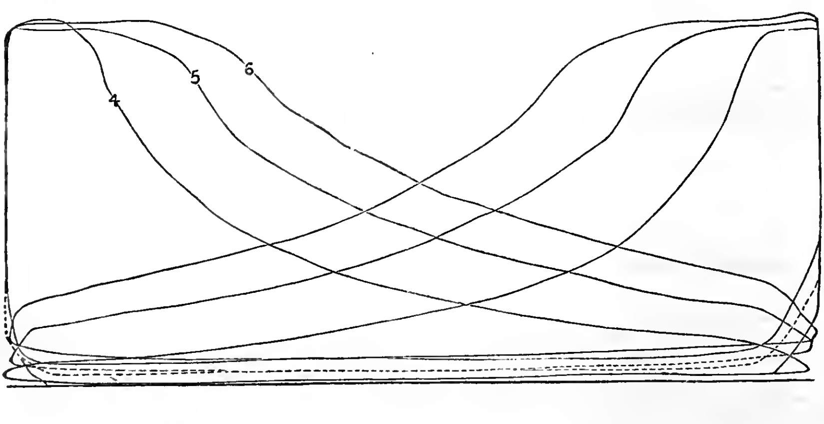
STEAMER "BACHE." SINGLE ENGINE, WITHOUT USING STEAM JACKET. INDICATOR SCALE, 40 LBS. PER INCH



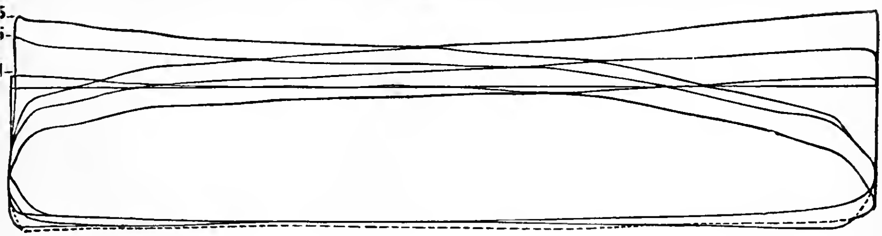
C.—Steamer "Bache." Single Engine, Water in Cylinder. Indicator Scale, 40 lbs. per inch.



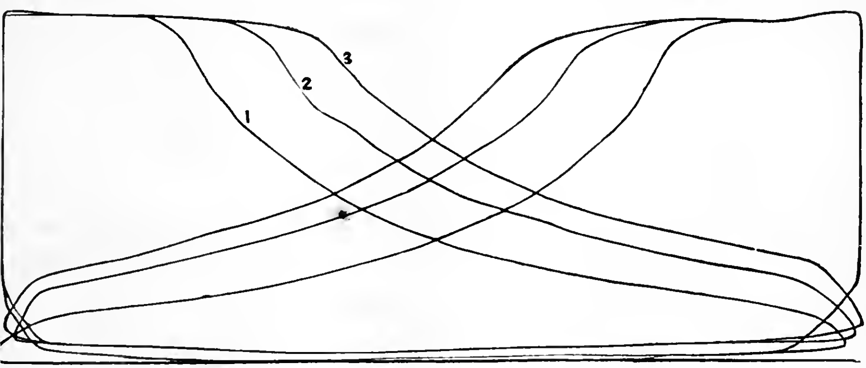
D 1.—Steamer "Bache." Compound Engine, Small Cylinder. Indicator Scale, 40 lbs. per inch.



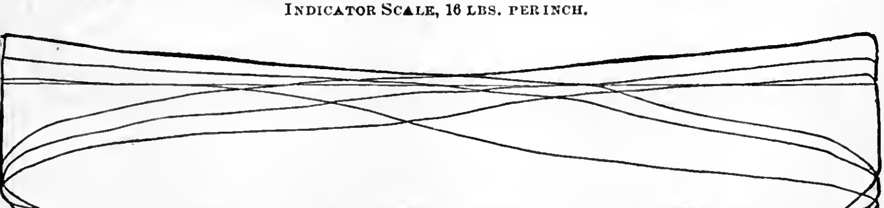
D 2.—Steamer "Bache." Compound Engine, Large Cylinder, using Steam Jacket. Indicator Scale, 16 lbs. per inch.



1.—Steamer "Bache." Compound Engine, Small Cylinder. Indicator Scale, 40 lbs. per inch.



E 2.—Steamer "Bache." Compound Engine, Large Cylinder, without using Steam Jacket. Indicator Scale, 16 lbs. per inch.



EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxix, page 285.]

The following are the principal dimensions and proportions of the boiler:

Diameter of the shell, ...	4 feet 1 inch.
Length of the shell proper, ...	6 feet 6 inches.
Total length of the boiler, including uptake,	7 feet 7 inches.
Number of furnaces, ...	1
Breadth of grate-surface, ...	1·96 feet.
Length of grate-bars, ...	4 feet 3 inches.
Area of grate-surface, ...	8·33 square feet.
Total number of tubes, ...	60
Outside diameter of six of the above tubes,	$2\frac{1}{4}$ inches.
Outside diameter of fifty-four of the above tubes,	2 inches.
Length of all the above tubes, in clear of tube-plates, ...	4 feet $10\frac{3}{4}$ inches.
Diameter of the chimney, ...	$10\frac{1}{2}$ inches.
Height of the chimney above the level of the grate-bars, ...	14 feet 9 inches.
Water-room in the shell, up to 4 inches above tubes,	36·7303 cubic feet.
Steam-room in the shell, above 4 inches above tubes,	11·9404 cubic feet.
Steam-room in the additional cylinder and connecting-pipe, ...	6·1493 cubic feet.
Total steam-room, ...	18·0897 cubic feet.
Cross area for draught over the bridge-wall,	1·2370 sq. ft.
Cross area for draught through the tubes, .	1·0918 sq. ft.
Cross area of the chimney, ...	0·6013 sq. ft.
Heating-surface in the furnace, . . .	16·6736 sq. ft.
Heating-surface in the back smoke-connection,	25·2137 sq. ft.
Heating-surface in the tubes, calculated for their inner circumference, ...	140·3494 sq. ft.

Heating-surface in the uptake, . .	3·4290 sq. ft.
Total water-heating surface, . . .	185·6657 sq. ft.
Steam-superheating surface in the uptake,	2·5153 sq. ft.
Ratio of the water-heating to the grate surface,	22·239 to 1·000
Ratio of the steam-superheating to the grate surface, ...	0·266 to 1·000
Ratio of the grate-surface to the cross area over the bridge-wall, ...	6·734 to 1·000
Ratio of the grate-surface to the cross area through the tubes, ...	7·630 to 1·000
Ratio of the grate-surface to the cross area of the chimney, ...	13·853 to 1·000
Weight of the boiler, including grate bars, bearers, chimney, and all doors and plates,	5,050 pounds.
Weight of water in the boiler, . . .	2,290 pounds.

SPACE OCCUPIED IN THE VESSEL BY THE MACHINERY, AND ITS WEIGHT.

The length in the vessel occupied by the machinery, including the fire-room, feed-water tanks, and coal-bunker, is 19 feet 8 inches. The feed-water tanks are placed along each side of the engines and boiler, so that the entire breadth of the vessel is occupied by the machinery and its appendages. The coal-bunker is forward of the boiler.

The weights of the machinery are as follows, namely:

	Pounds.	
Net weight of the engines proper, including crank-shaft, but excluding piping, flooring, etc., . .	1,400	
Weight of the stern-bearing pipe in dead-wood, and the dead-wood stuffing-box, ...	141	
Weight of the line-shafting and its couplings, . .	590	
Weight of the screw-propeller, ...	250	
Weight of all the piping, ...	150	
Weight of the boiler, including grate-bars, bearers, chimney, and all doors and plates, ...	5,050	
Weight of the water in the boiler, ...	2,290	
Weight of the felt, lagging, gum, putty and paint on the engines and boiler, ...	129	
Total weight of machinery, ...		10,000

	Pounds.	
Weight of feed-water carried in tanks, ...	8,500	
Weight of feed-water tanks, ...	3,200	
Weight of coal carried in bunker, ...	4,500	
Weight of coal-bunker, ...	600	
Total weight of feed-water and its tanks, and of coal and its bunker, ...		16,800

Total weight of all objects in the engineer department, 26,800 or 12 tons.

SCREWS.

The different screws employed in these experiments are of brass, and will be designated by letters. They are all of the same diameter, and have the same diameter of hub, except the Griffith screw, H.

Screws, A, C, E and F, were formed in the following manner: Two true screws were very carefully swept up in the sand by the same moulder from the same iron guides, and were cast of the same metal at the same time. Each of these screws has two blades, one opposite the other, and is $5\frac{1}{2}$ inches long in the direction of its axis. The pitch is uniform, and, by accurate measurement of the screws after they were cast, 5·136 feet. If the blades are viewed in projection on a plane parallel to the axis, their forward and after edges are parallel to each other, and at right angles to the axis. The outboard end of the screw-shaft was made to receive both screws at the same time, one being placed immediately in front of the other and touching, so that by bringing the after edge of the blades of the forward screw to coincide with the forward edge of the blades of the after screw, the propelling surfaces of both screws would be continuous, and they would thus form one two-bladed screw A, 11 inches long in the direction of the axis. Or, the blades of the after screw could be placed immediately behind those of the forward screw, in the direction of the axis, and they would thus form the Mangin screw F, 11 inches long in the direction of the axis. Or, the blades of the forward screw could be placed at right angles to those of the after screw, and thus form the four-bladed screw E, $5\frac{1}{2}$ inches long in the direction of the axis; for the fact that the blades of the after screw are recessed, as it were, $5\frac{1}{2}$ inches back of those of the forward screw, does not affect the results in the slightest degree, and the screw was the same as

though the four blades had been on the same hub of $5\frac{1}{2}$ inches length. Or, one of the screws could be used alone, when it was the two-bladed screw C, $5\frac{1}{2}$ inches long in the direction of the axis.

After the completion of the experiments with the screws formed as above described, one of them was cut through at right angles to the axis, so as to leave it $3\frac{1}{8}$ inches long in the direction of the axis and make the two-bladed screw D.

By using screw D in connection with screw C, bringing their propelling surfaces to be continuous, the two-bladed screw B was formed $8\frac{5}{8}$ inches long in the direction of the axis.

It will thus be seen that all the screws from A to F, both inclusive are composed of exactly the same physical surface, governed by the same co-efficient of friction on the water, and have exactly the same helicoidal form; the results from them are, therefore, free from the doubt which attends trials of screws having different physical surfaces, and, consequently, possibly different helicoidal forms, and different co-efficients of friction, though intended to be exactly the same.

Screw G is a three-bladed screw, with a pitch expanding gradually from 6 feet 6 inches at the forward edge of the blades, to 7 feet 6 inches at the after edge, making the mean pitch 7 feet, which it had by close measurement. The length of the blades, in the direction of the axis, at the periphery of the screw, is 7 inches; gradually increasing, thence to 11 inches length, in the direction of the axis, at the radius of 19 inches; from which point it gradually decreases to 6 inches length, in the direction of the axis at the hub. When the blades are viewed in projection on a plane parallel to the axis of the screw, their forward edge is nearly perpendicular to the axis. If the most forward part of this edge is made to touch this perpendicular, the contact will be at 19 inches radius, from which point the forward edge of the blade curves gradually back until it is, at the hub and at the periphery, $1\frac{3}{8}$ inch from the perpendicular. The thickness of the blade just above the fillet joining it to the hub, is $1\frac{1}{4}$ inch at the center. The weight of the screw is 250 pounds.

Screw H is a three-bladed Griffith screw, formed by trimming the blades of screw G into the Griffith shape, and bolting between them a hub made of wood, to the figure of the frustrum of a sphere 15 inches in diameter and 11 inches in height. This hub was well smoothed, painted, and varnished; its diameter is 0·28846 of the diameter of the screw, and both ends are flat and circular. The

length of the blades, in the direction of the axis, at the periphery of the screw, is 3½ inches, whence they curve gradually outward to the length of 11 inches, in the direction of the axis, at the radius of 19 inches, from which point they curve gradually inward to the hub, at which the length is 7½ inches in the direction of the axis. When the blades are viewed in projection on a plane parallel to the axis of the screw, they are pear-shaped, and the forward and after edges are arranged symmetrically on both sides of a perpendicular to the axis passing through the center of the blades. The pitch expands gradually from 6 feet 8 inches at the forward edge of the blade, to 7 feet 4 inches at the after edge, making the mean pitch 7 feet. The fraction used of the pitch in function of the surface and of the propelling efficiency of the surface is 0·24.

In the following table will be found the principal dimensions of the screws: For screws G and H, the mean pitch only is given, and the slip is always calculated for it. For these screws, too, the length given is the greatest length of the blades in the direction of the axis.

Table containing the principal dimensions of the screws employed in the following experiments.

Designation of the screw.	Diameter, in feet.	Diameter of Hub in feet.	Pitch, in feet.	Number of blades.	Length of each blade in direction of axis, in feet.	Fraction used of the pitch.	Projected area of the blades, on a plane at right angles to axis, in square feet.	Helicoidal area of the blades in square feet.
A	4·3333	0·50	5·136	2	0·9167	0·3570	5·1950	6·1321
B	4·3333	0·50	5·136	2	0·7187	0·2799	4·0730	4·8078
C	4·3333	0·50	5·136	2	0·4583	0·1785	2·0975	3·0661
D	4·3333	0·50	5·136	2	0·2604	0·1014	1·4755	1·7417
E	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
F*	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
G	4·3333	0·50	7·000	3	0·9167	0·3446	5·0140	6·8520
H†	4·3333	1·25	7·000	3	0·9167	0·2034	2·7495	5·2968

*Mangin screw. †Griffith screw.

MANNER OF MAKING THE EXPERIMENTS.

Before commencing the experiments, a very excellent dynamometer was constructed and applied to the screw-shaft for the purpose of measuring the thrust of the screw. It consisted of a single vertical lever, stiff enough not to spring under a considerably greater pressure than the screw was capable of giving, bearing by knife-edges of

steel against a brass ring free to move on guides in the direction of the screw-shaft, and having a turned recess in which was a loose brass ring carrying *lignum-vitæ* plugs or cylinders projecting beyond both sides of the loose ring; both ends of the plugs are bearing-surfaces, and are flat and at right angles to the grain of the wood. These surfaces were kept flooded with oil during the trials. The knife-edges bore against pieces of steel let into the movable brass ring.

The thrust of the screw was delivered against the *lignum-vitæ* plugs by a brass collar secured upon the screw-shaft abaft the regular thrust-collars. There were no collars on the screw-shaft abaft the dynamometer.

The guides of the movable brass ring carrying the loose ring in which the *lignum-vitæ* plugs were inserted, were two steel pins, one on each side of the shaft, fitting into holes of a little larger diameter bored through lugs cast upon the ring.

An accurately graduated steel spiral spring was attached to the upper end of the lever, which end also carried a pencil that traced the line of pressures continuously on a sheet of paper secured around a horizontal large diameter revolving-drum which received its motion from the screw-shaft through worm-wheels and worms. The lower end of the dynamometer lever, the other end of the spiral spring, and the guides of the movable brass ring, were, of course, attached firmly to the vessel. The ratio of the length of the vessel-arm of the lever to the length of the spring-arm, was 1 to 11. The dynamometer-diagram thus obtained, gave the thrust-pressures for every instant during each run of the vessel.

Two indicators were used: one of them was kept permanently in position on one cylinder, and the other on the other cylinder, during the experiments. Each indicator communicated with both ends of its cylinder, and before use was put in perfect adjustment, and had its spring tested.

A counter was attached to the screw-shaft, and registered the number of its revolutions.

The base for the experiments, or the course passed over by the vessel during each run, was a straight line 8,955 feet long, as given by the very accurate survey of Mare Island. It extended from the northern side of the dry-dock dolphins, or guard piers, to the northern side of the magazine wharf. This base was close under the lee of the high ground of the island, the wind over which was always in

the same direction, exactly at right angles to the base; and the water smooth.

During all the trials, the variation in the vessel's draught of water, and in the trim, was very slight. The velocity of the tide varied from nil to three geographical miles per hour.

With each screw eight experiments were made at the speeds, respectively, of 5, $5\frac{1}{2}$, 6, $6\frac{1}{2}$, 7, $7\frac{1}{2}$, 8, and $8\frac{1}{2}$ geographical miles per hour, as nearly as could be obtained. Each experiment consisted of six runs over the base, three in each direction, and the time of making them was selected when the tide had but little influence. The vessel's speed through the water during each double run was not only ascertained from the ranging marks at the ends of the base, but by means of a mercurial speed-gauge consisting of Berthon's modification of Pitot's tube.

This gauge was composed of a glass tube bent into the U-form; the ends of the tube were open, and the curved portion and a portion of the legs were filled with mercury. The top of each leg communicated by a gum pipe with the bottom of a separate air-chamber, and the top of each chamber communicated by another gum pipe with the upper portion of a brass tube closed at both ends. One of these brass tubes was placed within the other, the inner tube passing a few inches through the ends of the outer one by stuffing-boxes. The upper ends of the brass tubes were inside the vessel, and their lower ends protruded about 6 inches below the bottom of the vessel, 12 inches from the nearest side of the keel, and at about the middle of the vessel's length. The inner tube was the pressure-tube, and its interior received the pressure of the water through a hole of 1-32 of an inch diameter in its side, a little above its bottom, and in the directly ahead direction of the vessel. The larger tube was the neutral tube, and in its side, a little above its bottom, was a hole of 1-32 of an inch diameter with its axis at the angle of $41\frac{1}{2}$ degrees from the directly ahead direction. The diameter of the outer brass tube was 1 inch, and of the inner brass tube $\frac{5}{8}$ of an inch. A properly graduated scale being attached to the legs of the glass tube, measured by the difference of the level of the mercury in those legs, the vessel's speed in geographical miles per hour. When the vessel was motionless in still water, the mercury in the two legs stood at the same level. The vessel's speed by this gauge in a calm and at dead high or low water, being frequently compared with its speed at the same

time according to the shore-marks, was always found to exactly correspond.

In making the experiments, the vessel, at the intended speed, was brought opposite one end of the base and then run uniformly to the other, being kept in a straight line by an expert steersman. After passing the last end of the base a sufficient distance, the vessel was turned and the run repeated back in the same manner. The throttle-valve was always carried wide open, during the turnings as well as during the runs, and the steam-pressure varied but slightly throughout an experiment, the supply of steam required being always within the capacity of the boiler to furnish.

From the commencement of each run to its end, indicator-diagrams were taken as rapidly as possible from each end of each cylinder. The assistant engineers charged with this duty being very expert, and having the pencils and paper all previously prepared, the diagrams were taken with so little interval of time, that they may be considered continuous. The dynamometer-diagram, taken by another engineer, was continuous from the beginning to the end of the run.

An observer stationed always at the same part of the vessel, gave the signal the instant he was opposite the ranges at the ends of the base; and, at the same moment, two other observers took, one the time to a second, and the other the number on the counter. Thus, the time of making each run, and the number of revolutions made by the screw in that time, were exactly ascertained.

During each run, an observer noted at the end of each half minute the vessel's speed through the water, by the speed-gauge; and at the end of every minute the steam-pressure in the boiler, as given by a spring-gauge. There were also noted during each run, the temperatures of the external atmosphere, of the engine-room, of the feed-water entering the boiler, and of the sea-water; also, the atmospheric pressure as given by an aneroid barometer. Every care was observed in the conduct of the experiments to insure extreme accuracy. Although many of the quantities noted were not necessary to the main purpose of the experiment, yet the results from them are interesting in other points of view.

(To be continued.)

Chemistry, Physics, Technology, Etc.

THE TREATMENT OF TANK OFFAL AND THE GASES FROM RENDERING TANKS.

*With a description of some of the processes in operation in Chicago.**

By Dr. Ben. C. Miller, Sanitary Superintendent.

To sanitarians, and indeed to the citizens of all large cities, the questions how to care for animals, how to kill them, and the proper method of caring for the products of slaughter houses, are exceedingly grave ones; questions that not only concern the health of the community, but the comfort of individuals.

In considering the business of slaughtering and the care of the products, I shall refer to the manner in which it was conducted in Chicago up to 1865, mention the improvements made since that time, and give descriptions of some of the apparatus now in use.

At the period referred to, live stock was received at the different yards in the city; the principal ones being at Twenty-second street. The accommodations were not first class, the pens were not planked in many cases, and the animals were compelled to stand in the mud.

In 1865 the new yards of the Union Stock Yard Company were completed, and the cattle, etc., were subsequently received at that point. The entire yards were drained as well as the nature of the ground would admit, the roadways and alleys macadamized, and the pens for cattle planked; while those for sheep and hogs were in addition roofed to protect them from the weather. Water is furnished throughout the yards from an artesian well. The superintendent, Mr. John B. Shennan, who is absolute in authority, has a large force constantly employed in taking care of the pens and keeping them clean, every effort being made to render the animals comfortable.

Inspectors pass through the yards constantly, and all maimed and diseased cattle found are not permitted to leave, but are killed and sold to a company who own a rendering establishment on the Calumet

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* Read before the American Public Health Association, in Philadelphia, November, 1874.

river, some twenty miles from the city, whither the carcasses are taken and rendered for their fat. In this way maimed and diseased animals are prevented from going into the market and being sold for food.

The following table shows substantially the number of animals received during each of the first three years after the opening of the yards:

Hogs, ...	688,140
Sheep, ...	179,880
Cattle, ...	330,301

While in 1873 the receipts were as follows:

Sheep, ...	291,734
Hogs, ...	4,337,750
Cattle, ...	761,428

An increase of 4,199,581.

Previous to 1865 nothing had been done towards the care of gases generated in the rendering tanks. In many houses closed tanks were not in use, the cooking being generally done in open kettles; and when tanks were used, the gases and steam were permitted to escape into the open air, and the offensive odors were carried by the southwest wind over the city. Every year brought to the city a large increase in the number of animals received, and a corresponding increase in the number and capacity of the packing houses, with attendant disagreeable odors. Nothing had been done to utilize the tank refuse when removed from the tanks; the only question was how to get rid of it. Before the river was frozen, boatloads of it were dumped into the lake several miles from shore; and when navigation closed it was buried on the prairies, giving variety to the city smells when the summer warmed it up.

The quantity of tank refuse or offal a single season will yield can be readily estimated when it is known that an ox or a cow gives 50 lbs., a hog 20 lbs., and a sheep 7 lbs. The total amount cared for during 1873 was 22,784,360 pounds.

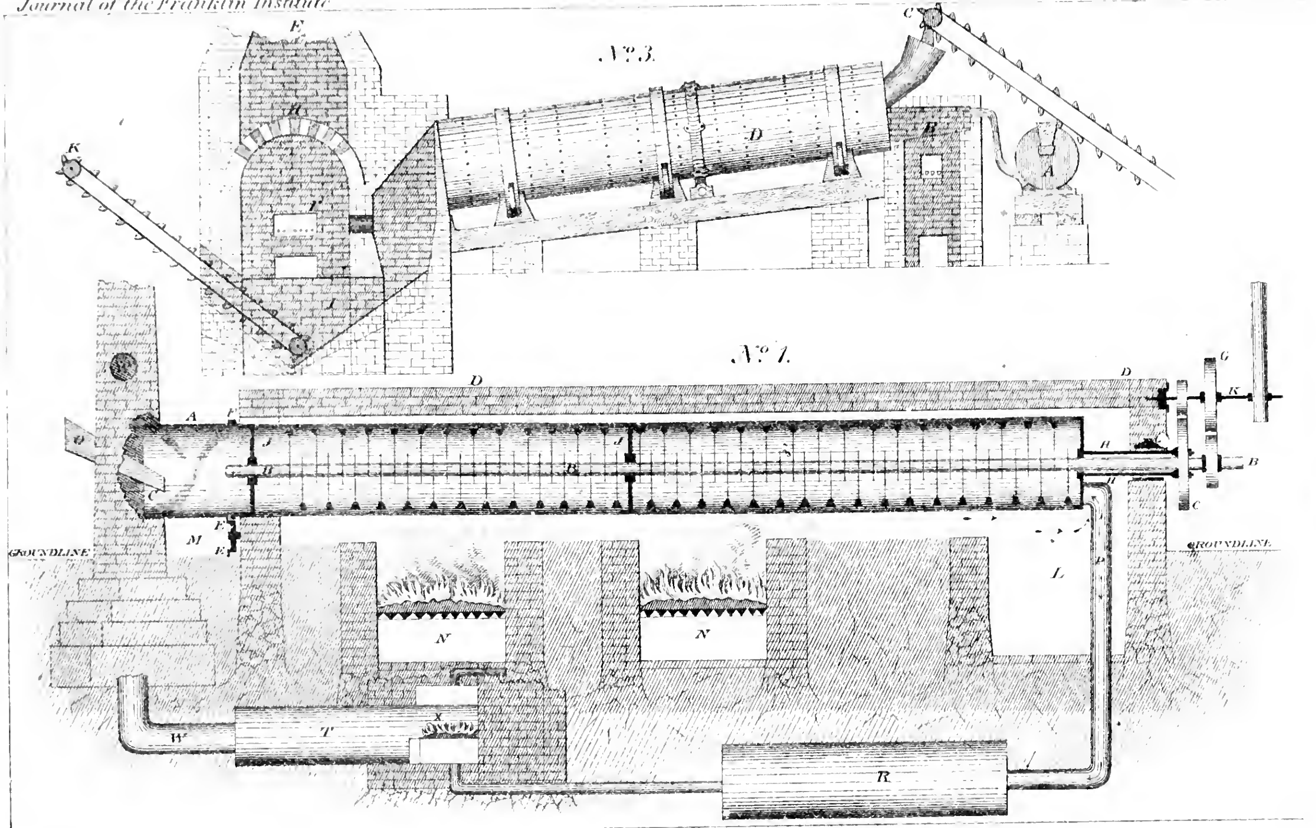
The first effort made toward the disposal of the gases was in the form of a regulation of the Board of Health, compelling the use of tanks from which the steam passed through a coil of pipes into a condenser, and thence, with a portion of the gases, into the street sewer.

This was a marked improvement over the old way, but was not at all satisfactory, since the gases escaped through the man holes in the street sewers into the atmosphere. In some of the houses the steam and gases were passed into the chimneys and thence into the air. This was all that was done in this direction; but steps had been taken to care for the tank refuse.

Baugh's dryer (see Plate No. 1) was procured by one company, and an attempt made to turn the refuse into a fertilizer. It was successful so far as the drying was concerned, but the odors emitted from the smoke stacks were unendurable, and the company's works were indicted as a nuisance.

This drying machine consists of a revolving cylinder thirty feet long and three feet in diameter, inside of which is an axle with three arms or agitators equidistant from one another, which revolve in the same direction as the cylinder. The heat is supplied by several fire places underneath, and also by a current of hot air which passes through the cylinder. When in position that end is highest where the material is fed into the machine; the refuse coming in contact with the agitators and hot air, it is kept constantly in motion until it passes out at the other end in a dry state. The material runs through in about five minutes, and from one to two tons can be dried in an hour. The gases generated during this process pass into a condenser and thence into a chamber (a comparatively new invention), the temperature of which is 2100 degrees. Here they meet a flame and dripping hydro-carbon oil, and, as claimed, are burned, the residuum going up the chimney. My observations of the working of this machine have extended over a period of two years, and in my opinion the dryer cannot be used without giving offense unless the gas chamber is added and kept in perfect order. When not connected with the dryer the volume of smoke and steam passing through the chimney is enormous; when it is used, scarcely any smoke is noticeable, and the disagreeable odor is lessened to such an extent that the drying process can be carried on without giving serious offense.

Another apparatus used at several of the packing houses, for manufacturing the refuse into a fertilizer, is known as Edwards' machine (see Plate No. 2). It consists of a cylinder, varying in size according to the work to be done, with a chamber underneath in which air is heated and passed through an inner plate into the cavity of the cylinder where it comes in direct contact with the material.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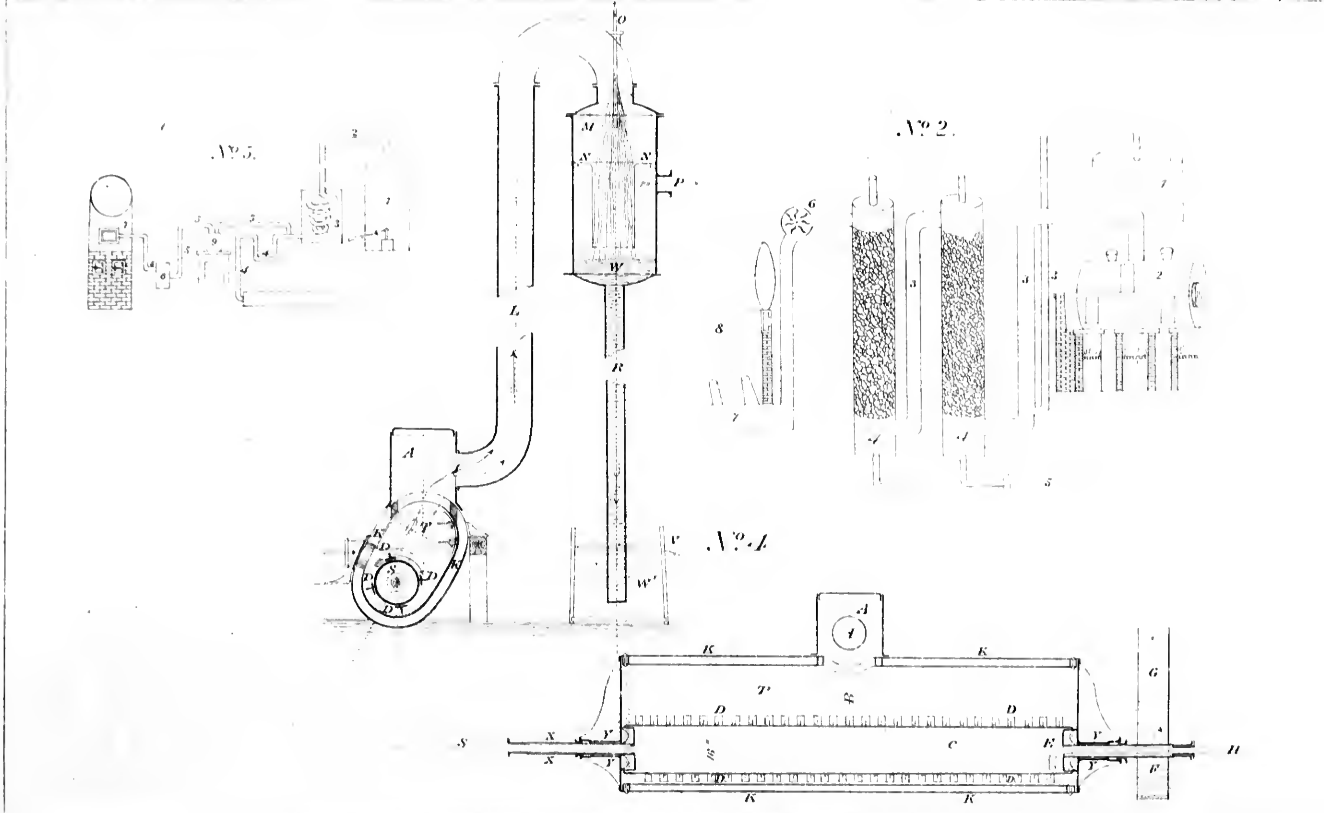
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In the centre of the cylinder is an axle with extending arms, the axle being revolved by machinery, and keeping the refuse in constant motion. The heat is applied under the cylinder, none entering it except a small quantity which escapes through the openings in the heated chamber.

About one and a half tons can be dried at a charge, taking about three hours. As originally constructed, no provision was made for destroying the gases, which were permitted to escape into the open air. Lately, however, the owners of the machine have attached Bradley's process for destroying the gases, and also added escape pipes to the rendering tanks, those connected with the sewers having been discontinued.

Bradley's process consists of a pipe leading from the dryer and tanks to an upright boiler thirty feet in height, filled with brick so placed that water can percolate freely and escape from the bottom into a pipe connected with the sewer. From the top of the boiler a large pipe leads to the base of a second upright boiler, which is also filled with bricks in the same manner as the other. Extending from the top of the latter boiler is a pipe leading to a rapidly rotating fan which draws the gases and steam from the dryers and tanks and drives them into a chamber underneath the grate bars or furnaces, where they pass through the fire, and, as is claimed, are destroyed. In passing through the boilers, the steam and vapory portion of the gases are brought in contact with a stream of water which flows through the bricks, and are condensed, escaping ultimately with the water into the sewer, the dry gases only being driven under the furnace. I cannot state fully the merits of this machine, as it has been in use only a short time; but that it is a great improvement over the old method there can be no doubt.

Another method is known as Storer's. This dries differently from either of those described. Baugh dries by heat applied externally, hot air passing through the machine; Edwards also applies heat externally, but adds a hot air chamber with openings which allow the hot air to come in contact with the material. In the Storer patent, heat is applied on the inside of the cylinder by using pulverized fuel, the offal coming in contact with a flame and being dried rapidly in a temperature ranging from 2300 to 2700 degrees, the large percentage of water (from 50 to 75 per cent.) preventing it from burn-

ing. This machine (see Plate I, Fig. 3), which will dry about ten tons of raw material an hour, consists of a brick-lined cylinder varying in size according to amount of work to be done, placed on an incline having at one end a fire place and at the other a smoke stack. Underneath are friction rollers, on which it revolves.

The material is fed into the furnace end by an elevator, where it encounters the pulverized fuel, and going rapidly through it comes out at the base of the smoke stack, and there it is conveyed away through another elevator. Passing through such intense heat and drying so rapidly, enormous quantities of steam and gases are evolved. These are carried into a combustion chamber at the base of the stack. This chamber is an inverted cone, perforated, and opens into the smoke stack. At the bottom of the cone is a grate on which is a coal fire. Above the fire, through an opening in the side of the cone, a jet of the pulverized fuel is projected, igniting as it enters and keeping the chamber at a white heat. By the passage of the gases through the chamber and the grate it is claimed that they are destroyed.

This machine has been in operation for two years, and has given general satisfaction. Many experiments have been made to test the thoroughness of the destruction of the gases, and all were very satisfactory, even a wet blanket placed over the smoke stack to dry retaining no odor; and it was demonstrated that if the gases were passed through a sufficiently high temperature, they were neutralized or destroyed.

The latest machine put in operation is known as the Tobey dryer (see Plate II, Fig. 4). It consists of an oblong cylinder twelve or fifteen feet in length, made of boiler iron, and so constructed as to surround the material with a steam jacket. Inside is another cylinder, hollow and some sixteen inches in diameter, covered with teeth, which comminutes the offal and facilitates the drying process. The cylinders are heated by the surplus steam from the boilers used in the packing house proper. The dryer is fed by a contrivance which supplies a given quantity at a time, the material passing through in about ten minutes. On the top of the outer cylinder is a dome, through which the gases pass upward to a pipe leading to a condenser composed of a chamber and a copper pipe with a blind end, perforated with hundreds of minute holes.

The steam and gases entering the chamber come in contact with fine streams of water trickling from the perforations and the steam

part of the gases is condensed, and escapes with the water into the street sewer.

This apparatus has not been long in use and one of its most valuable features seems to be in the economy of working. It can be operated by the surplus steam of a packing house, and its capacity is such that the offal can be disposed of as fast as the fat is removed from it, thus preventing accumulations and permitting no material to grow rancid.

This includes the more prominent machines (with the exception of the Hogel machine which is heated by steam) in use in Chicago for the purpose indicated.

By the use of the above machines the tank refuse can without doubt, be cared for without giving serious offense, but to do so the utmost vigilance is required in working the different processes. That the work will be done without offense to the public, there can be no doubt, for the material is too valuable to lose, and the Chicago public, from the past improvements are satisfied that the work can be done without offense and will insist on its being done so.

In considering the above processes I have spoken incidentally of the escape pipe of the rendering tanks being attached to the Bradley condenser and the destroying of the gases in the furnaces.

It is claimed that the combustion chamber of Baugh or Storer will destroy the tank gases if the proper connections are made.

THE GASES FROM RENDERING TANKS.

After the Board of Health compelled the use of closed tanks and the use of condensers, many experiments were made looking towards the destroying of tank gases.

Among the successful ones was the experiment of Mr. James Turner which resulted in Turner's patent, (Plate II, Fig. 5) which carbonizes the gases and destroys them. After the steam is condensed, the gases are carried off by a pipe to an iron tank, fifty feet from the building where they pass through gasoline or other hydro-carbon oils, and are brought back to the furnace and burned under the boilers. The amount of gases generated from the tanks used in a large packing house is sufficient, after being carbonized, to generate a large quantity of heat, and will by this method save a large percentage of fuel.

That these gases can be burned in the open air without offense has been frequently demonstrated to the writer and others, and at present the patentee is placing a gasometer in connection with his carbonizer

in which the gas will be stored in sufficient quantities to light the packing house.

That each year brings improvements in the packing houses and diminishes the number of nuisances both in quantity and intensity is evident. The packing house of to-day is totally different from that of ten years ago.

Aside from the improvements in caring for refuse and gases, much has been done in other directions. The sewerage is now looked after and every effort is made to have perfect ventilation, both by external windows and by mechanical means of the latest and most approved plans. In the place of wooden floors in the cellars, stone floors have in some of the recently erected houses been substituted.

Packers have learned that the more perfect the arrangements of the house, the more fully sanitary requirements are met, more work can be done and a better class of meat cured.

I think the management of some of the houses has demonstrated that they can be conducted without serious offense, and if in the future improvements progress in the same ratio as they have progressed in the past six or eight years, and packers take an interest in adopting them and doing their work well, there will be slight cause for complaint against packing houses.

New Method of Developing Magnetism.—Tommasi has recently stated in a paper communicated to the French Academy of Sciences, that when a current of steam under a pressure of five or six atmospheres is driven through a copper tube one-eighth to one-quarter of an inch in diameter, wound in the form of a helix, a bar of iron placed in the axis of this helix, becomes so strongly magnetized that a needle placed several centimeters distant from this *steam-magnet*, is decidedly attracted. The magnetism remains in the bar so long as the current of steam continues.

Preservation of Metallic Sodium.—According to Bottger, if sodium be placed in alcohol until its surface becomes brilliant, and then in naphthalic ether chemically pure, and finally in a concentrated solution of naphthaline in naphthalic ether, the metal may be preserved unalterable with its luster unimpaired, for a long time.

ON THE MECHANICAL EQUIVALENT OF HEAT.

By M. Jules Violle.*

The principle of the equivalence between heat and work, we owe originally to Mayer[1]; though Joule also formulated it at about the same time[2]. So important was this discovery that it is not too much to say that it formed the foundation of an entirely new science. Attention was thereby called at once to a principle enunciated twenty years before by Sadi Carnot[3]; and soon the principle of Carnot, generalized by Clausius[4], was united to that of Mayer, to constitute the basis of what is now known as the mechanical theory of heat.

These two fundamental principles, first postulated by Mayer and Sadi Carnot, have modified to a remarkable extent the ideas which were held up to that time, upon the nature of heat. The consequences which have been drawn from them by Helmholtz, Clausius, Joule, Sir W. Thomson, Macquorn Rankine and Hirn, have justly attracted the attention of the entire scientific world; indeed, some of these deductions have already been the cause of introducing important improvements into industrial mechanics. The essential point, however, in the application of these new principles, is obviously the exact value of the numerical coefficient which enters into Mayer's theorem, that is to say, the mechanical equivalent of heat. By this term is meant the number of kilogram-meters (or of foot-pounds) of force which is produced by a unit of heat integrally transformed into work; or, what is the same thing, the number of kilogram-meters (or of foot-pounds) of force which it is necessary to expend in order to produce a unit of heat, assuming that the integral transformation of heat into work is a success. The researches which have been undertaken in or-

[* The following paper, which we translate from the *Revue Industrielle*, was read before the Marseilles Industrial Scientific Society, and is an excellent *resumé* of the whole subject. Its author, M. Violle, is a professor in the scientific faculty at Grenoble.—Ed.]

1. Mayer, *Die organische Bewegung und der Stoffwechsel.* Heilbronn, 1845.
2. *Philosophical Transactions*, 1850, 61.
3. Carnot, *Reflexions sur la puissance motrice du feu*, 1824.
4. *Poggendorff's Annalen*, xciii, 481, 1854.

der to determine this fundamental number are very numerous, especially if we consider how short the time which has elapsed since Mayer for the first time enunciated the equivalence of heat and work.

These researches have been undertaken from widely different standpoints. Indeed it is evident from the great generality of the theorem, that by methods exceedingly diverse, the numerical value of the mechanical equivalent of heat may be accurately obtained. From this most fortunate possibility, therefore, there arises a means of controlling the individual results of each experimenter. In this paper, it is my purpose to enumerate these results, and to specify those which appear to be most worthy of confidence.

The most striking example, probably, of the transformation of work into heat, is that which is furnished by friction. As early as 1798, Count Rumford, struck with the enormous amount of heat set free in the boring of cannon, made an experiment in the Royal foundry at Munich which has since become celebrated. He succeeded by means of the heat alone produced by the friction of a blunt rod against the bottom of a hollow cylinder of iron, in boiling, in the course of two hours and a half, a mass of water of over ten liters[5]. J ule first made an exact measure of the heat set free by friction, and compared it accurately with the work absorbed, in 1849[6]. His experiments, which were very numerous and were conducted with great care, were made with water and mercury, and cast iron, and gave him for the mechanical equivalent of heat the number, 424·9, as the mean of a large number of closely concordant results. The value thus determined, coincided almost exactly with that which Joule had himself determined in 1843, while studying the friction of water in straight tubes[7]. Subsequently, Favre measured, by means of his calorimetric apparatus, the heat evolved in the friction of steel on steel, and thence deduced 413 as the value of the mechanical equivalent of heat[8]. About the same time, Hirn published the results of analogous experiments made by him[9]; the friction of liquids gave him 432, and the compression of lead, 425. It must not be forgotten that all these friction experiments present difficulties which are well nigh insur-

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5. *Philosophical Transactions, abridged*, xviii, 286
6. *Philosophical Transactions*, 1850, 61.
7. *Philosophical Magazine*, III, xxiii, 442, 1843.
8. *Comptes Rendus des Seances de l'Academie des Sciences*, xlvi, 337, 1858.
9. Hirn, *Recherches sur l'equivalent de la chaleur*, 1858, 1.

mountable. The measure of the work done is especially delicate, since all the work expended is not converted into heat; a portion more or less considerable being lost in the form of sensible motion, such as vibrations of surrounding bodies and of the air, without the possibility of measuring it. We should not then be surprised that the numbers obtained in this way, as given above, differ among themselves by the small quantities mentioned.

If in friction, we see an excellent example of the transformation of work into heat, the inverse transformation of heat into work appears more evident still in thermic engines, especially in those which are moved by steam. Hirn has succeeded in measuring with great exactness both the heat communicated to the boiler of a steam engine, and the total work performed by the engine[10]. These experiments, made by means of the powerful steam engines of a spinning factory, near Colmar, cannot. it is evident, lead to an exact value of the mechanical equivalent of heat (Hirn obtained the number 398); but they have a very great importance in establishing and also in popularizing, so to speak, the actual theory of heat.

The steam engine is by no means the only thermic motor employed in the industrial arts. Electro-magnetic engines may also be regarded as thermic machines, deriving their power from the heat evolved by the solution of the zinc in each cell of the battery and transported throughout the circuit by means of the current. The experiments of Favre[11] have shown in a most satisfactory manner that it is at the expense of a certain quantity of this heat that an electro-magnetic engine produces mechanical work; and in measuring the work performed and the corresponding absorption of heat, Favre has obtained another value for the mechanical equivalent of heat, 443. This number, it will be noticed, differs but little from the exact value. It is necessary to remark here also, that these determinations are extremely delicate, and that in the experiments of Favre, the equivalent sought having for its expression the quotient obtained by dividing 131·4 by 0·296, the divisor 0·296 itself being the difference of two quantities of heat measurable scarcely to one thousandth, this difference may very probably have an error of 0·02. This error if admitted would enable us to derive from the data of Favre, the value 435. Again it is possible to deduce the

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10. Hirn, *loc. cit.*, 20.

11. *Annales de Chimie et de Physique*, III, xl, 293, 1854.

numerical value of the mechanical equivalent of heat simply by measuring the heat evolved in a wire through which an electric current passes. We know, according to the law of Joule[12], that the heat evolved by a current is proportional to the product of the square of the strength of the current by the resistance of the circuit. Now Clausius has shown that the coefficient of proportionality is the exact reciprocal of the mechanical equivalent of heat[13]. If then, we measure at the same instant the heat which a given current produces, the strength of this current, and the resistance of the circuit, the equivalent sought can be easily calculated. This has been done by Quintus Icilius[14], who making use chiefly of Weber's most valuable researches[15] on the absolute measure of currents, has obtained 392 as the equivalent; a value considerably different from the probable one. The difference, however, does not exceed the limits of uncertainty attaching to the use of the large number of constants which it is necessary to determine, and which themselves are not easy to obtain by experiment.

Instead of having its origin in the chemical reactions taking place in the cells of the battery, the heat produced by electrical currents may be itself the result of a direct transformation of mechanical work. It is this condition of things which takes place when, by the expenditure of a certain amount of work, a conducting wire is moved in presence of a magnet or of a current. The heating which is produced under these conditions, has been measured by Joule, very early in the history of thermo-dynamics, by means of a tube full of water revolving between the poles of an electro-magnet[16]. Indeed by this method the very first determination of the mechanical equivalent of heat was made. The number obtained by Joule, 460, is a remarkably close approximation; although the various values of which this number is the mean are not very accordant, ranging between 322 and 572. This comes, without doubt, from the fact that the measurement of the heat was not made by a method sufficiently exact; that the correction for cooling was a little uncertain; and lastly, from the

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12. *Philosophical Magazine*, III, xix, 260, 1841.
13. *Poggendorff's Annalen*, lxxxvii, 415, 1852.
14. *Poggendorff's Annalen*, ci, 39, 1857.
15. Weber, *Electro-dynamische Maasbestimmungen.* (*Memoires de la Société Royale Saxonne de Sciences; Leipzig*, 1856, *tome* v.)
16. *Philosophical Magazine*, III, xxiii, 263, 434, 435, 1843.

much more important fact that the temperature of the water of the tube was measured by two thermometers placed at the two extremities of the tube, there being nothing to guarantee that the temperature should be the same at all points of the liquid. Indeed it is, on the contrary, much more probable that, with a constant velocity of rotation, a permanent condition of things is established in which the temperature varies regularly from the centre toward the ends. Le Roux has repeated these experiments, making use of the powerful magneto-electric machines of the Alliance Company[17]. He finds for the mechanical equivalent of heat the numbers 442, 462, and 470, the mean being 458. The method employed by him, even, for measuring the heat, is also somewhat uncertain. Foucault had, however, long before, given to Joule's experiment, a remarkable form, in which the heating becomes manifest in a very short period of time.

Between the poles of a powerful electro-magnet, says Foucault[18], I placed the rotating disk of a gyroscope. This disk is made of bronze having a toothed pinion upon its axis, by means of which it was connected with a train of wheel-work, in order to drive it. By means of a crank, worked by hand, a velocity of 150 to 200 turns per second can easily be given to the disk. In order to render the action of the magnet more effective, two pieces of soft iron placed above the bobbins, lengthened the magnetic poles and concentrated the force in the vicinity of the rotating body.

When the apparatus is put in motion with a high velocity, the current of six Bunsen cells passed through the electro-magnet, arrests the rotation in a few seconds as if an invisible brake had been applied. This is really the experiment first made by Arago[19], and developed by Faraday. If now the crank be forced to turn in the attempt to give to the apparatus its former velocity, the resistance encountered requires the application of a certain amount of power, which, disappearing as such, accumulates effectively as heat in the interior of the revolving body.

By means of a thermometer inserted in the disk, we may follow step by step the progressive elevation of the temperature. Having taken, for example, the apparatus at the surrounding temperature of 16° Centigrade, the thermometer was seen to rise successively to

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17. *Comptes Rendus des Séances de l'Academie des Sciences*, x, 414, 1857.
18. *Annales de Chimie et de Physique*, III, xlv, 316, 1855.
19. *Annales de Chimie et de Physique*, II, xxiii, 213, 1826.

20°, 25°, 30° and 34°. Then the phenomenon had become so developed as not to require the use of thermometric instruments. The heat produced was sensible to the hand.

Some days afterward, the battery being reduced to two cells, a flat disk made of copper was raised in temperature during two minutes of motion, to 60°.

This experiment is one by which a measurement of the mechanical equivalent of heat may be most admirably made. Two conditions only are necessary and sufficient to make it certain that the heat evolved in the experiment is the exact equivalent of the work expended in maintaining the rotation uniform:

1. It is necessary that the disk should be, at the end of the experiment, in precisely the same condition as at its beginning.

2. It is necessary that the heating of the disk should be the only effect produced.

Both these conditions are satisfied in the experiment.

1. Consider the beginning and the end of the experiment. At these two periods of time, the disk is precisely in the same physical condition, except of course as to temperature and to the other effects dependent upon this. When, then, by immersion in the liquid in the calorimeter, the disk is returned to its initial temperature or to a temperature differing from this by an exceedingly minute amount, it is restored to identically the same physical condition as before the experiment.

2. Leaving the axle out of account for the moment (since its influence upon the result can be estimated without difficulty) the apparatus is reduced to a disk turning freely in the air, without any friction against external bodies, at least, if we except the friction against the surrounding air, which may be regarded as insignificant in consequence of the great mobility of the air and the perfect symmetry of the moving body. If then. the useful work employed in maintaining the rotation be measured, it seems at first sight entirely certain that the heating of the disk is the only phenomenon produced by the observed expenditure.

When, therefore, we consider only the phenomena as they are presented to our senses; when we observe the rotation of the disk maintained by a continual expenditure of force, and notice the gradual heating of this disk during the entire duration of the experiment, the proposition above stated appears to us incontestable. But if we ex-

amine into the matter more closely, a serious objection presents itself to the mind, an objection which Joule himself first suggested (though he formulated it in a very obscure manner), and by which he accounted for the singular disagreement of his experiments with this method. We have, in fact, neglected up to the present time, an intermediate phenomenon; the motion is transformed into heat only by means of electricity. The immediate action of the electro-magnet upon the disk when in motion is to develop in it, by induction, electric currents; and it is these currents which heat the disk. But even if it were true that the work expended to maintain the rotation of the disk was transformed entirely into electricity, is it quite certain that all this electricity is transformed into heat? In order that it may be, it is necessary that the heating of the disk be the only effect produced by the currents. But even if the currents thus generated within the disk do not cause either luminous phenomena or perturbing mechanical effects, have we not to fear that they will give rise to phenomena of induction, thus creating by their influence electric currents in the two polar masses of the electro-magnet? I answer they will not; because I have shown by experiments specially instituted to test this question[20], that as soon as the velocity of the disk becomes uniform, there are no induction currents circulating in polar masses of the electro-magnet, and hence, consequently, there is no reaction between the disk and the electro-magnet. Moreover, these results have since been confirmed by direct experiments made by Jacobi[21]. The reason of this result appears to me entirely obvious; in every experiment, as soon as the disk attains the uniform velocity which is maintained throughout, the electric currents which are developed by induction in this disk, maintain a constant intensity and preserve in space a constant position. We may therefore consider these currents, of the form and distribution of which we have nothing now to say, as absolutely fixed so soon as equilibrium is reached. It is the displacement of the material of the disk with reference to these currents which produces the heating which is observed. But now, if the currents do not change either in strength or in position, there certainly can be no effect of induction produced on external conductors; a conclusion which direct experiment fully confirms.

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20. *Annales de Chimie et de Physique*, September, 1870.

21. *Comptes Rendus des Séances de l'Academie des Sciences*, January, 1872.

In consequence of the facts now stated I was led to the belief that I could employ advantageously Foucault's apparatus for measuring the mechanical equivalent of heat[22]. And by means of it, using disks of various metals, I have obtained with copper 435·2, with tin 435·8, with lead 437·4, and with aluminum 434·9. The experiments made with the disks of copper and of aluminum are, it seems to me, worthy of more confidence than the others, and in consequence I propose 435 as the mechanical equivalent of heat.

The exactness of this number has been confirmed by certain very important researches, made by an entirely different method. From the general properties of gases, we can, it is well known, deduce the value of the mechanical equivalent of heat by means of the formula:

$$E = \frac{\alpha\, p_0 v_0}{C - c}.$$

Now Regnault has made exact determinations of the density, the coefficient of dilatation and the specific heat, under constant pressure, for air, for hydrogen, and for carbonic acid. Moreover, the uncertainty which has so long existed upon the exact value of c, has recently also disappeared, thanks, too, to Regnault, who by a careful study of the propagation of sound through gases, has found for $m = \frac{C}{c}$ the value 1·3945.

I have not space to describe here the experimental processes employed by Regnault in his gigantic investigation on the propagation of sound in gases[23] which has given us this determination of m. I will content myself with giving some of the results, taken from the resumé which the author has himself published:

According to the formula of La Place, the velocity of propagation of a sonorous wave is the same, whatever be the intensity of the wave; but according to the complete theoretic formula, this velocity ought to be as much greater as the intensity of the wave is more considerable. Now, experiment teaches us that in a cylindrical pipe, such as is used for conducting gas or water, the intensity of a wave does not remain constant, but that it successively diminishes; and this the more rapidly in proportion as the tube has a smaller section.

22. *Comptes Rendus des Séances de l'Academie des Sciences*, June, July, 1870.

23. *Memoires de l'Institut*, (*Academie des Sciences*,) xlvii, 1871.

This fact was observed in all Regnault's experiments; but I shall refer here only to the mean velocity of a wave produced by the discharge of a pistol, which is propagated in dry air at zero, and which can be followed from the moment of starting until the time when it has no longer sufficient intensity to throw into vibration the membranes which indicate its passage. The experiments above referred to were made: 1st, in the Ivry gas main, the interior section of which is 0·108 meter and its length 566·7 meters; 2d, in the main along the military route, whose diameter was 0·300 meter and its length 1905 meters; and 3d, in a large sewer of the boulevard St. Michel, 1·10 meters in diameter and 1590 meters in length.

1. In the main, whose diameter was 0·108 meter, the diminution of the mean velocity of the same wave, reckoned from the instant of its departure, but taken successively over longer and longer distances, and making use of the reflections at the two ends of the tube, is well defined. 2. The mean velocities for waves produced with the same charge of powder, and for equal distances, are much greater in the main of 0·300 meter than in that of 0·108 meter. 3. The mean velocity of propagation in the main, whose diameter was 1·10 meters, diminished less rapidly than in the main, whose diameter was 0·300 meter.

These differences are still more marked when we compare the mean limiting velocities in the three conduits; that is to say, the velocities which correspond to a wave so far enfeebled since its production that it can no longer affect the membranes. For these velocities, the following are the figures obtained: 326·67 meters in the main of 0·108 meter, the total distance traversed being 4055·9 meters; 328·98 meters in the main of 0·300 meter, the total distance being 15240·0 meters; and 330·52 meters in the main of 1·100 meters, the distance being 19851·3 meters.

In all of these experiments, the wave was produced by the same charge of powder. The membranes remained the same in all, and consequently ceased to record in each of the three conduits, when the wave had reached the same degree of enfeeblement. If then the enfeebling of the wave comes only from the loss of *vis viva*, which is communicated to the walls of the tube, the mean limiting velocity should be the same in the three mains since the wave has the same intensity at the instant of starting and precisely the same at the instant when it makes its last mark upon the membrane. These limiting velocities being, on the contrary, very different, it is necessary to

conclude that the walls of the tube exert upon the air in the interior some other action than that just indicated; an action which diminishes notably its elasticity without changing sensibly its density. In order that this action of the walls upon the elasticity of the gaseous medium may be absolutely nil, it is necessary that the tube have an infinite diameter. But it ought still to be very small in as large mains as 1·10 meters; hence, we may say that the mean velocity of propagation, in dry air at the temperature of zero, of a wave produced by the discharge of a pistol, following it from the muzzle of the barrel, up to the instant when it is so far enfeebled that it can no longer throw the most delicate membranes into vibration, is 330·6 meters.

In the experiments made by Regnault at the camp at Satory to determine the velocity of propagation of waves in free air by the old method of reciprocal cannon discharges, he has obtained for the mean velocity of a sonorous wave in free air, dry and at zero, 330·7 meters, a number which coincides almost exactly with the preceding one.

Without insisting here upon the immediate importance of these results, I shall consider now only their utility as bearing upon the question now under discussion. This will appear when we state that the theoretical formula for the velocity of sound in gases, this velocity being once accurately known, enables us to calculate the ratio, $\frac{C}{c}$, which experiment does not give us directly; and hence also to calculate, by the formula above given, the value of E. Employing the numbers obtained in the above experiments of Regnault, calculation gives $E = 436{\cdot}08$.

If now we compare with this value, the number which I obtained by a completely different process, 435, and also that which Edlund[24] had previously deduced by measuring the calorific effects which are produced during the change of volume of metals, 431, it will be very evident that the number generally adopted, 425, is too small and that it is necessary to substitute for it 435 kilogram-meters, as the true mechanical equivalent of heat.

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24. *Poggendorff's Annalen*, cxxxvi, 1865.

DESCRIPTION OF M. KASTNER'S NEW MUSICAL INSTRUMENT, THE PYROPHONE.*

By M. Dunant.

Sound is, in general, according to natural philosophers, a sensation excited in the organ of hearing by the vibratory movement of ponderable matter, whilst this movement can be transmitted to the ear by means of an intermediate agent. Sound, properly called musical sound or tone, is that which produces a continuous sensation, and of which one can appreciate the musical value. Noise is a sound of too short a duration to be appreciated well, as the noise of a cannon, or else it is a mixture of confused and discordant sounds like the rolling of thunder. For a single sound to become a musical sound, that is to say, a tone corresponding to one of the intonations of the musical scale, it is necessary that the impulse and, consequently, the undulations of the air should be exactly similar in duration and intensity, and that they should return after equal intervals of time. In its change to the musical state, however dull and confused the noise may be, it becomes clear and brilliant. Like the diamond, after having been polished and cut according to the rules of art, it has the brilliancy for the ear which the former has for the eye. This is what takes place in singing flames. Very imperfect in its beginning, hoarse, roaring, or detonating, it does not come nearer the musical sound, properly so called in the chemical *harmonica*, as it is termed, still, by means of reiterated trials the sound of the single flame in the tube, the *lumen philosophicum*, as it is elsewhere called, can it be musically produced in every case?

It has long been known that a flame traversing a glass tube under a certain pressure produces a musical sound. The eminent savant, Professor Tyndall, to whom the greater part of the deep questions in physics are no mysteries, has studied singing flames, but it must be admitted that singing flames have only penetrated into the dominion of art in consequence of the discovery made by M. Frederic Kastner of the principle which allows of their being tuned and made to produce at will all the notes of the musical scale, to stop the sound

* A paper read before the Society of Arts, February 17th, 1875.

instantaneously and mechanically; as in keyed instruments the sound is regulated and subdued as desired. It is thus that the modest *harmonica chimique, lumen philosophicum* of natural philosophers has, in the pyrophone, attained to the character of a real musical instrument; this happy result supports the remark that the observation in nature of the phenomenon of sound may conduct man, if not exactly to the invention of music, at least to endow the art with resources which increase its power. The sound of the pyrophone may truly be said to resemble the sound of a human voice, and the sound of the Æolian harp; at the same time sweet, powerful, full of taste, and brilliant; with much roundness, accuracy, and fullness; like a human and impassioned whisper, as an echo of the inward vibrations of the soul, something mysterious and indefinable; besides, in general, possessing a character of melancholy, which seems characteristic of all natural harmonies. The father of this young philosopher, a member of L'Institut de France, and a learned author, who died in 1867, treating on cosmic harmonies, insists on this peculiarity:—

"The harmonies of nature," said he, "which in their terrible grandeur as well as in their ineffable sadness, have ever charmed the philosopher, poet and artist, are most often stamped with a character of vague melancholy, from the influence of which the mind cannot escape. It is especially when the noise of the world is hushed that these powerful harmonies produce the most overpowering and poetical effects."

It characterizes, for example, the sound of the echo, the sound called harmonics, and many others which are included in the range of musical tones, defined further on under the name of *chemical and sympathetic music.* We have the most remarkable examples of these in the sound of the Æolian harp. Science, as well as philosophy, poetry, and musical art, is interested in the further study of these sounds. In Germany, Goethe and Novalis, in France, Jean Paul, and many others, have eagerly appreciated the bond which unites natural harmonies to the most elevated instincts, and to the most ideal aspirations of the human soul.

Professor Tyndall has recognised the fact that in order to render a flame musical, it is necessary that its volume be such that it should explode in unison with the undulations of the fundamental note of the tube, or of one of its harmonics. He also asserts that when the volume of the flame is too great, no sound is produced; he demon-

strates it, by increasing the flow of gas. Professor Tyndall has also called attention to this fact, that in order that a flame may sing with its maximum of intensity, it is necessary that it should occupy a certain position in the tube. He shows this by varying the length of the tube over the flame, but he does not specify the proportions which must exist between the flame and the tube for obtaining this maximum intensity of sound. M. Kastner's merit is in having shown that when two or several flames are introduced into a tube, they vibrate in unison, and produce the musical maximum of sound when they are placed one-third the length of the tube, and if these two flames are brought in contact, all sound ceases directly, a phenomenon M. Kastner demonstrates to be caused by the *interference of sounding flames.* Here is a question, lately scarcely thought of, of which M. Frederic Kastner has determined the laws, at the same time making a most remarkable application of them in creating an instrument which reminds one of, and may be mistaken for the sound of the human voice.

A very simple mechanism causes each key to communicate with the supply pipes of the flames in the glass tubes. On pressing the keys, the flames separate and the sound is produced. As soon as the fingers are removed from the keys, the flames join, and the sound ceases immediately. These new experiments made by M. Kastner upon singing flames should cause all makers of musical instruments to turn their attention to inventions connected with sound. If two flames of suitable size be introduced into a glass tube, and if they be so disposed that they reach one-third of the tube's height, measured from the base, the flames will vibrate in unison. This phenomenon continues as long as the flames remain apart, but the sound ceases as soon as the two flames are united. If the position of the flames in the tube is varied, still keeping them apart, it is found that the sound diminishes while the flames are raised above the one-third until they reach the middle point, where the sound ceases. Below this point the sound increases down to one-fourth of the tube's length. If at this latter point the flames are brought together, the sound will not cease immediately, but the flames will continue to vibrate as a single flame would. M. Kastner, for his first experiments, used two flames derived from the combustion of hydrogen gas in suitably constructed burners. The

interference of the singing flames is only produced under special conditions. It is certain that the length and the size of the tubes depends upon the number of flames. The burners must be of a particular shape; the height of the flames does not exercise much effect upon the phenomenon. From a practical point of view, the numerous experiments effected by M. Kastner during several years, have resulted in the construction of a musical apparatus on an entirely new principle, to which he has given the name of *Pyrophone;* it may be called a new organ, working by singing flames, or rather by vibrations caused by means of the combustion of these flames. This instrument may be constructed from one octave to a most extended compass.

The *British Review* humorously remarks that the pyrophone will naturally be valuable in winter, and that in America it has already been recommended to families as a means of warming small apartments, and perhaps an economical stove may be added to it for the culinary exigencies of straightened households.

The pyrophone will have in the future a poetical mission to fill in the music of concerts. A great number of composers and musicians have already admired this new organ performing by the singing of flames, or rather by vibrations determined by means of the combustion of these flames. They think it will be of great advantage in cathedrals and churches, as the most extended compass can be given to the instrument.

L'Année Scientifique, by M. Figuier, declares that the pyrophone is assuredly one of the most original instruments that science has given to instrumental music. In the large pyrophone which M. Kastner has constructed, and which they have not yet been able to bring to London, an artist can produce sounds unknown till the present time, imitating the human voice, but with strange and beautiful tones, capable of producing in religious music the most wonderful effects. So says *Le Journal Officiel de l'Exposition de Vienne.*

Journals and reviews abroad have unanimously mentioned with praise this new instrument, both from a musical as well as from a scientific point of view.

M. Henri de Parville, in *Les Causeries Scientifiques*, gives a large space to the consideration of "Singing Flames," and states that "gas music" made its *debut* at the Vienna Exhibition of 1873. *La Nature* and *La Revue des Sciences*, edited by M. Tissandier, believe

that this new instrument is destined to produce the most remarkable and unexpected effects in the orchestras of lyric theatres and in large concerts. The chandeliers of the theatre, besides serving to light it, may be converted into an immense musical instrument:—

"When the pyrophone is played by a skillful hand, a sweet and truly delicious music is heard; the sounds obtained are of an extraordinary purity and delicacy, recalling the human voice."

The inventor has prepared a large and beautiful singing lustre, with a dozen or fifteen jets, which can be placed in the richest or most comfortable drawing-room. This lustre may be used at concerts or balls, for it can play all the airs in dance music. It will be worked by electricity, so that the performer who plays may be seated in a neighboring room. The effect will be perfectly magical. The future has other surprises for us, for our houses. The most unexpected applications of scientific principles are daily the result of the skillful efforts of learned men.

Without reckoning Professor Tyndall, who is so well known and esteemed on the Continent, many other learned men, English, German, Austrian, (like Schaffgotsch), and Frenchmen have already studied singing flames, but no one had previously thought of studying the effects produced by two or several flames brought together, till M. Kastner, who, by means of delicate combinations and ingenious mechanism, has produced the pyrophone.

Frederic Kastner, the inventor of the pyrophone, showed from his earliest age a very decided taste for scientific pursuits. His parents, whose fine fortune permitted them to satisfy the taste of their son for study, gave him facilities often denied to genius. They frequently traveled; the first thing which arrested his attention was a railway; this pleased him much; he had a passion for locomotives, just as some children have for horses. He was only three years old when he examined the smallest details with a lively feeling of curiosity. Later on, when he tried to reason and explain his impressions, he overwhelmed with questions those who surrounded him, wishing to learn the mechanism of these great machines, and the mysterious force which sets them at work. But what more especially charmed him was, when the train stopped at the station, the fiery aspect of the jets of gas emerging suddenly from the darkness. At this sight he shouted with delight; such was his enthusiasm that he seemed as if

he would jump out of the arms of those who held him, in order to rush towards the jets of flames, which exercised upon him a sort of fascination.

Steam and gas, in their modern application to locomotion and lighting, were the first scientific marvels which struck the mind and the sense of the child. He studied music under the skillful direction of his father. From the age of fifteen years, in studying gas particularly, his attention was directed to singing flames. The mysteries of electricity were also at this time the object of his study. The researches to which he gave himself up carried him on to invent a novel application of electricity as a motive force. He patented this invention. On the 17th March, 1873, the Baron Larrey, member of the Academy of Sciences of Paris, presented to the *Institut de France* young Kastner's first memoir on singing flames, which laid down the following new principle:—

"If two flames of a certain size be introduced into a tube made of glass, and if they be so disposed that they reach the third part of the tube's height (measured from the base) the flames will vibrate in unison. This phenomenon continues as long as the flames remain apart; but as soon as they are united the sound ceases."

Passing on to his experiments, M. Kastner thus gives his account:—

"I took a glass tube, the thickness of which was $2\frac{1}{2}$ millimeters; this tube was 55 centimeters long, and its exterior diameter measured 41 millimeters. Two separate flames of hydrogen gas were placed at a distance of 183 millimeters from the base of the tube. These flames, while separated, gave F natural.

"As soon as the flames are brought together, which is done by means of a very simple mechanism, the sound stops altogether. If, letting the flames remain apart, their position is altered until they reach one-third of the total length of the tube, the sound will diminish gradually; and it will cease completely if the flames go beyond one-half the length of the tube; under this (one-half the length of the tube) the sound will increase until the flames are brought to one-fourth of the tube's total length. This latter point being reached, the sound will not cease immediately, even if the two flames are placed in contact one with the other; but the two flames, thus united, continue vibrating in the same manner as a single flame would.

"The interference of the singing flames can only be obtained under certain conditions. It is important that the length of the tubes should be varied according to the number of the flames, the height of which has only a limited action or influence over the phenomenon;

but the special shape of the burners is a matter of considerable importance.

"These experiments, which I undertook two years ago, induced me to construct a musical instrument, possessing quite a novel sound, which resembles the sound of the human voice. This instrument, which I term the Pyrophone, is formed by three sets of keys (claviers) disposed in a similar manner to that employed for the conjunction of the organ-key tables; a very simple mechanism causes every key of the different sets to communicate with the supply pipes in the glass tubes. As soon as a key is pressed upon, the flames, by separating, create a sound; but when the keys are left untouched, the flames are brought together and the sound stops."

In consequence of this communication a Commission from the Academie des Sciences de Paris was selected for the examination of this curious invention, consisting of Messrs. Jamin, Regnault, and Bertrand, three distinguished members of that academy, who showed a lively interest from a scientific point of view in M. Kastner's discovery. After fresh experiments, M. Kastner has succeeded in substituting the ordinary illuminating gas for hydrogen gas in working this pyrophone, and his friend, the Baron Larrey, was again the interpreter to l'Academie des Sciences of this new discovery, which much facilitates the employment of the luminous musical instrument. M. Kastner thus expresses himself in his new report presented to the *Institut de France*, 7th December, 1874:—

"The principal objection which has been made to the working of the pyrophone, is the employment of hydrogen gas. From a practical point of view, this gas presents several inconveniences. It is difficult to prepare; it necessitates the use of gas holders, whose size may be considerable. Besides, there is some danger in its use. I have, therefore, given up using hydrogen gas, and for a year I have experimented on the means of applying common illuminating gas to the pyrophone, which is always easy to procure. In the first experiments which I attempted with two flames, with illuminating gas, in a glass tube, I was unable to obtain any sound, which proved unmistakably the presence of carbon in the flames. Whilst the sound was produced in a very clear manner with the pure hydrogen gas, that is to say, without there being any solid foreign matter in the flames, it was impossible to make the tube with illuminating gas vibrate, when placing the flames in an identical condition. It was necessary, then, by some means or another to eliminate the carbon, a result at which I arrived by dint of the following method:—

"When the flame of ordinary gas is examined, and this is introduced into a tube made of glass, or of any other material (metal, oilcloth, cardboard, etc.), this flame is either illuminating or sounding.

"When this flame is only illuminating, that is to say, when the air contained in the tube does not vibrate, it presents a lengthened form, and is pointed at the top. Besides, it swells towards the middle, and flickers on the least current of air. On the contrary, when the flame is sounding, that is to say, when the necessary vibrations for the production of sound are produced in the tube, its form is narrow, and large at the top. Whilst the air of the tube vibrates, the flame is very steady. The carbon in a great measure is eliminated as if by some mechanical process.

"Sounding flames proceeding from lighting gas are in effect enveloped in a photosphere which does not exist when the flame is merely luminous. In the latter case the carbon is burnt within the flame, and contributes in a great degree to its illuminating power.

"But when the flames are sounding, the photosphere which surrounds each of them contains an exploding mixture of hydrogen and oxygen which determines the vibrations in the air of the tube.

"To produce the sound in all its intensity, it is necessary and sufficient that the whole of the explosion produced by the particles of oxygen and hydrogen in a given time, should be in agreement with the number of vibrations which correspond to the sound produced by the tube.

"To put these two quantities in harmony, I have thought of increasing the number of flames so as to increase also the number of the explosions from the mixture of oxygen and hydrogen in the photospheres, and thus determine the vibration of the air of the tube. Instead of two flames of pure hydrogen, I put four, five, six, etc., jets of lighting gas in the same tube.

"I have besides observed, that the higher a flame is, the more carbon it contains.

"I have then immediately been obliged to diminish the height of the flames, and consequently to increase the number so that the united surface of all the photospheres may suffice to produce the vibration of the air in the tube.

"The amount of carbon contained in the whole of the small flames will always be much less than the quantity of carbon corresponding to the two large flames necessary to produce the same sound. In this manner I have been able with separated flames to obtain sounds whose tones are as clear as those produced by hydrogen gas. When these flames, or rather when the photospheres which correspond to these flames, are put in contact, the sound instantly ceases. The carbon of lighting gas, when the flames are sounding, is certainly almost entirely eliminated—in fact, it forms upon the interior surface of the sounding tube at and below the height of the flames a very visible deposit of carbon, which increases whilst the air of the tube vibrates. I can now affirm that the Pyrophone is in a condition to act as well with the illuminating gas as with pure hydrogen. The phenomenon

of interference is produced exactly in the same condition with the two gases, the same flames occupy the same position in the tube, that is the third part of the tube's length measured from the base. In addition to the phenomenon of interference, I believe I shall be able to describe a novel process by aid of which the sound produced by burning flames in a tube can be made to cease.

"Supposing that one or several flames, placed in a tube a third of its height (measured from its base), determine the vibration of the air contained in this tube; if a hole is pierced at the one-third of the tube, counted from the upper end, the sound ceases. This observation might be applied to the construction of a musical instrument, which will be a species of flute, working by singing flames. Such an instrument, from a musical point of view, will be very imperfect, because the sound will not be so promptly or sharply stopped, as when the phenomenon of interference is employed. If, instead of making the hole at the third, it is made at the sixth, the sound will not cease, but it will produce the sharp of the same note. In all these experiments I clearly detected the formation of ozone while flames cause the air in the tube to vibrate. The presence of this body can, moreover, be ascertained by chemical re-agents scientifically known."—Given before the *Academie des Sciences*, 7th December, 1874.

Professor Tyndall, at a lecture on 13th January, at the Royal Institution, showed experiments according to the new principle, with an apparatus of nine flames, which worked during the evening in tubes of different sizes.

Hygroscopic Paper.—Percy Smith has made a series of interesting researches upon the hygroscopic properties of a bibulous paper impregnated with concentrated solution of cobalt chloride. This paper is very sensitive to atmospheric variations, being blue in a dry atmosphere and becoming red when the air becomes humid. He suspended strips of this paper upon the wall of a room opposite a window opening to the south. The window remained open during the day. By the side of the strips were two thermometers, with wet and dry bulbs. Four observations a day were made, and these were continued for a year. The principal results obtained are given in the annexed table, in which the variations of color from red to blue are designated by the numbers 1 to 10. It will be seen that when there was a difference of 13° between the two thermometers, the paper remained entirely blue, and

that it became red only when this difference fell to between 1 and 3 degrees. This fact is easily explained when we remember that the paper once turning blue cannot take a darker tint by any farther diminution of humidity in the surrounding air.

Dates of the Observations.		Dry Bulb Thermometer.	Wet Bulb Thermometer.	Difference.	Coloration of paper.	Remarks.
July 8th,	1st observation,	72	60	12	9	Very warm day.
	2d "	74	61	13	10	
	3d "	70	59	11	8·5	
July 10th,	1st "	74·5	65	9·5	8	Day warmer than the 8th, blue color less intense.
	2d "	77	67	10	7	
	3d "	79	67	12	9	
Sept. 30th,	1st "	62	56	6	3	Barometer at rain.
	2d "	64	61	3	1	
Oct. 1st,	1st "	62	58	4	0·5	Rain during the night. Barometer rising.
	2d "	63	59	4	1	
Oct. 2d,	1st "	59	55	4	0·5	Barom. falling. Barom. stationary.
	2d "	58	53	5	1	Cleared off.
Oct. 23d,	1st "	52	48	4	1	North wind.
	2d "	55	54	1	0	West wind.
December 3d,		13	10	3	2	Heavy frost.

From these results, it appears that the absolute temperature of the atmosphere has no relation whatever to the actual color of the paper; the variations of tint being precisely the same for the same differences between the thermometer readings, whatever the actual temperature at the time of observation. Paper impregnated with cobalt chloride solution, may therefore be employed to indicate readily, and precisely the hygrometric state of the air, and thus to control in a very effective way the hygrometers usually employed.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXIX. JUNE, 1875. No. 6.

EDITORIAL.

ITEMS AND NOVELTIES.

Useful Effect of the Human Machine as Compared with that of Fire-arms.—It is well known that the useful effect of steam engines varies between three and ten per cent. of the total available work calculable from the transformation of the heat of the fuel into motion. It is also well known that the work done by men and by animals is the result of the combustion of the food which they eat; and that, further, it is to the same transformation of heat into motion, that fire-arms owe their efficiency. But the actual useful effect of the two latter transformations is not as well known. The following details upon this subject, therefore, taken from a paper by M. de Saint-Robert, recently published in the *Revue Scientifique*, are not without interest.

When the human body is at rest, the only effect of the chemical actions going on within it, is simply to produce the heat necessary to maintain its temperature constant at 37° C (98° F.) But if it is in motion, only a portion of the chemical action is transformed into heat, the rest appearing as mechanical work. As in all machines moved by heat, so here; if we divide the work done by the number of units of heat (calories) expended, we shall obtain the mechanical equivalent of heat, which is 425 kilogrammeters (772 foot-pounds.)

In order to obtain the heat thus expended, it would be necessary: 1st, to calculate the heat which would be obtained by burning all the food taken into the body as well as by burning the body itself; 2d, to calculate the heat lost externally, during the whole of life, together with that which would be evolved by the combustion of all matters eliminated from the body during the same time, and by the combustion of the body immediately after its birth; and 3d, to subtract the second of these values from the first.

We have just seen that the useful effect of a steam engine does not exceed on an average, seven per cent. Let us now see what is the actual useful effect of the human machine used as a source of power. The greatest amount of work which a man can do, as is well known, is that which he does in raising his own body in walking up a gentle slope. The measure of the work thus done is of course the product of the weight of his body by the height to which it is raised. The work thus actually stored up, may be utilized by employing the descent of the man to raise a weight equal to his own to the height from which he came. Now actual experiment has proved that, working in this way, a man can perform without over fatigue, a work of 280,000 kilogrammeters (2,000,000 foot-pounds.) On the other hand, the daily food of a working man is, on an average, according to the calculations of Moleschott:*

Albuminoid substances, . . .	130	grams.
Adipose substances, . . .	84	"
Adipogenic, or fat-forming substances, (starch, dextrin, sugar), . .	404	"
Inorganic salts, ...	30	"
Water, ...	2800	"
	3448	grams.

The combustion of these substances would give:†

Albuminoid substances, . . .	650	calories.
Adipose " . . .	762	"
Adipogenic " . . .	1471	" ‡
	2883	calories.

* *Physiologie der Nahrungsmittel*, 2d Ed., p. 223.

† Ranke, *Physiologie*, p. 793.

‡ Calculated on the supposition that the adipogenic substances are reduced to their equivalent in starch. Hence, by reason of the carbon they contain, they are equivalent to 449 grams of sugar.

The mechanical labor equivalent to these 2883 calories is represented by 1,225,275 kilogrammeters, (8,880,000 foot-pounds.) Dividing now the daily work done by the work theoretically possible calculated from the food taken, we obtain for the efficiency of the human machine 0·229; or about 23 per cent. This result accords very closely with that which Helmholtz has given. This eminent physicist estimated the external work of a man to be one-fifth of the available mechanical power contained in his food. The human machine then is greatly superior, so far as effectiveness is concerned, to the steam engine. But it is very much more costly. Indeed, according to the estimate of the work of a man given above, it would be necessary to have eight men to obtain one horse power. Now estimating the cost of coal at ten dollars a ton, and the wages of a man at forty cents, the expense of this amount of power for each day of eight hours, would be about ten cents for the steam engine, and three dollars and twenty cents for the eight men.

Fire-arms, too, belong to the great class of thermic machines. They are employed for the purpose of transforming into motion a portion of the heat produced by the combustion of the powder. The gases which are evolved during the combustion of the charge drive the projectile and the gun in opposite directions, impressing upon them opposite velocities. At the same time, a certain quantity of heat disappears, being transformed into work. The total work accomplished by the powder is equal to the product of the weight of the projectile by the height to which it would rise if projected vertically in a vacuum, plus the product of the weight of the gun, by the height due to its velocity. This latter product, however, being ordinarily very small in relation to the former one, may be neglected. We may measure, therefore, with sufficient accuracy, the effect of the powder by the work done on the projectile. Hence it is obvious that the useful effect of a fire-arm is measured by the ratio between the work actually done, and that which is the equivalent of the quantity of heat set free by the combustion of the charge.

Taking, for example, a rifled cannon, the diameter of the bore of which is 7·5 centimeters, (3 inches), the shell of which weighs about 3·7 kilograms, (8·3 pounds), and the firing charge of which is 0·55 kilogram, (1¼ pounds), it is easy to calculate its effectiveness. Experiment has shown that the velocity of the shell when it leaves the mouth of the cannon is about 400 meters (1300 feet) per second.

The height from which this projectile would have to fall to acquire this velocity, is 8158 meters (26,800 feet). Consequently the work actually done by the powder is equal to 30,185 kilogrammeters (219,000 foot-pounds).

On the other hand, Bunsen and Schischkoff have found by direct experiment, that the heat evolved by the combustion of a kilogram of gunpowder is equal to 619·5 calories. Hence the heat evolved by the above charge of 0·55 kilogram is equal to 340·7 calories. The mechanical work corresponding to this amount of heat is 144,798 kilogrammeters (1,050,000 foot-pounds). Comparing this, which is the possible mechanical work, with the actual work done on the projectile as given above, the ratio is 0·208 for the effectiveness of the cannon; that is to say, about 21 per cent.

Velocity of Magnetization and Demagnetization of Wrought Iron, Cast Iron, and Steel.—The question of the rapidity with which iron acquires and loses its magnetism is an exceedingly important one in all cases where electro-magnets are employed in rapid transmission or in time determinations. We find in the *Revue Industrielle*, the following note upon this subject, communicated to that journal by M. Deprez :—

"In the course of my researches upon electro-magnets and their application to the registering of very rapid phenomena, researches, the first results of which were communicated to the Academy of Sciences, I have been led to investigate the question of the influence of the iron itself upon the duration of the magnetization and demagnetization. For this purpose, I have used a registering apparatus, in which the pieces of iron constituting the electro-magnet are removable, while all the other parts, the coils, armature, style, etc., remain the same; so that the only change in the results obtained must be due to the influence of the metal which forms the electro-magnet. In order to measure the time of the magnetization and demagnetization, I have employed the electric chronograph, which was described in my earlier communication. The metallic portion of the electro-magnets, which I place successively within the magnetizing helices, consists of two cores, two millimeters in diameter and thirteen millimeters long. The coils through which the current passes, contain 14 meters of wire, one-fifth of a millimeter in diameter. The battery used was a single Bunsen element, as modified by M. Dulaurier.

Finally, the varieties of iron examined were the ordinary wrought iron of commerce, a specially soft telegraphic iron, malleable cast iron, gray cast iron, and cast steel drawn into bars and tempered.

The results which have been obtained in this investigation were entirely unexpected. They prove that the soft iron, the ordinary wrought iron, the malleable cast iron, and even the tempered steel require very nearly the same period of time for their magnetization and demagnetization; namely,

For the demagnetization, ...	0·00025 second.
For the magnetization, (approximate), .	0·00150 "

The gray cast iron gave the best result of all, the time required for its magnetization, being only about one-thousandth of a second. This metal, therefore, is altogether the best to be used when the object is to attain the greatest possible rapidity in the transmission of signals.

In general, then, these facts prove that with the registering apparatus actually employed, perfectly distinct signals can be obtained at intervals of one three-hundred-and-fiftieth of a second, whatever the kind of iron used in the electro-magnets; and that if the cores of the magnet are made of gray cast iron, the interval between successive signals may be reduced to one five-hundredth of a second. It is necessary to say, however, that I do not refer to signals succeeding each other regularly at intervals of 1-350th or 1-500th of a second; in this case the number of signals which could be transmitted would considerably exceed 350 to 500 per second.

I am inclined to believe that this superiority of cast iron depends upon its molecular structure and has no relation to the quantity of carbon which it contains. Hence I purpose examining wrought iron which has been cast and not hammered, and which, I am confident, will surpass in the rapidity of its action all the irons which I have hitherto examined. It is my intention to give before long some details of my experiments on this subject, and some facts concerning the application of my registering apparatus as an electric chronograph for artillery purposes.

It is important to observe that the absolute time required for magnetization and demagnetization which is given above, does not include the time occupied by the style in making its record. It is by adding this time to that required for the magnet to act that the values 1-350th and 1-500th of a second are obtained. This therefore repre-

sents the total duration of a signal, and includes the demagnetization, the time of fall of the style, the magnetization and finally the return of the style to its primitive position. Moreover these numbers are correct only when but a single cell of the battery is employed, the number of signals transmitted per second, increasing with the intensity of the current."

Magnetization of the Rails on Railways.—M. Herzog, engineer-in-chief of the Hungarian railways, after a series of experiments on the magnetization of rails, gives the following as his conclusions:

1. The rails which are taken up and replaced after several years of service, do not by any means deserve to be called powerful magnets, since a steel rail about 40 square centimeters, (6·16 square inches) in cross section, manifests immediately upon its removal, a magnetic force scarcely equal to that of a saturated steel plate half a square centimeter in section. It is to be observed, however, that steel rails possess a much higher magnetic power than rails of ordinary iron.

2. Rails in place are also magnetic, and this whether the fish-plates are removed or not, provided there is between them the space usually allowed for expansion in all well-constructed lines.

3. Rails removed from the roadbed and piled up show traces of magnetism even after many months. This persistance of the effect is more pronounced in Bessemer rails than in those of ordinary iron.

4. A rail thrown out of use in consequence of fracture, shows on the two surfaces of separation opposite polarities. This is precisely the same fact which is observed when a magnetized bar is fractured; there are as many magnets as there are pieces.

5. Entirely new rails, which have never been in actual service, acquire feeble magnetic properties when they are arranged in piles and placed parallel to the magnetic meridian. This remark applies more particularly to steel rails, which, under the influence of a few blows with the hammer, are converted into permanent magnets.

This last observation leads M. Herzog to the conclusion that all these phenomena are attributable to terrestrial magnetism, and are only a confirmation of the following theoretical principles:

a. A bar of iron placed in the direction of the dipping needle, becomes a magnet under the influence of terrestrial magnetism. The same is true for any bar of iron placed in the magnetic meridian; its magnetic intensity diminishes in proportion, as the angle between the

two increases. This fact is very noticeable with rails laid on a curve; the more they vary from a north and south direction, the less intense is the magnetism at their ends.

b. A bar of iron exposed for a long time to the influence of terrestrial magnetism, becomes a permanent magnet.

c. For steel rails, the effect is more prompt, and more intense than for iron ones. Under the action of the hammer, they become permanent magnets. This latter effect is produced daily upon rails in use, since they are submitted at the same time to the combined influence of terrestrial magnetism and the jars produced by the passage of trains.

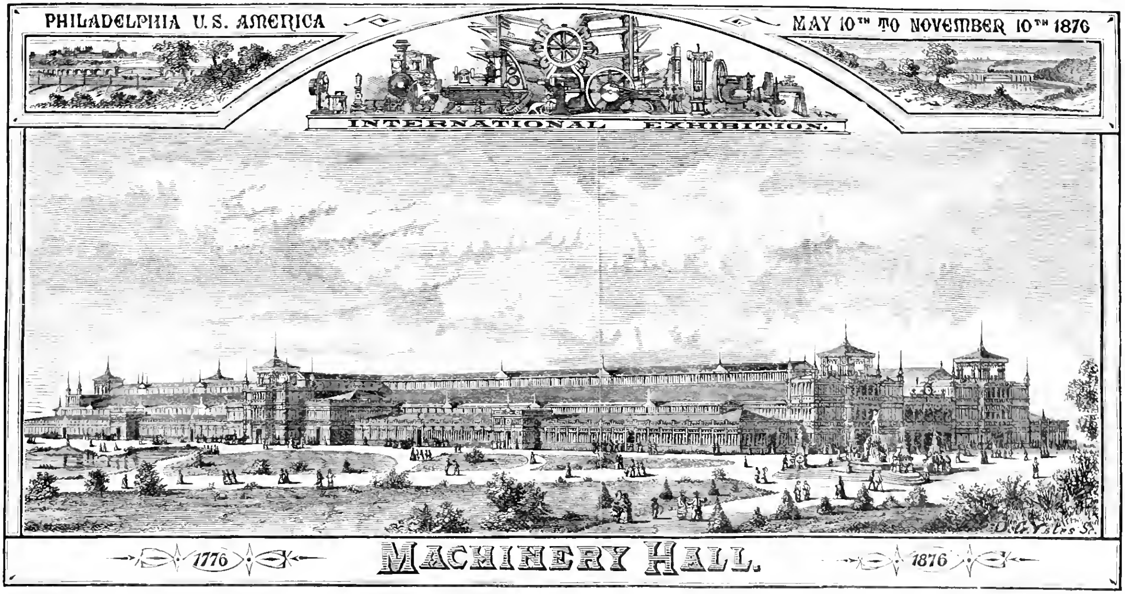
A Locomotive on Feet.—The well-known French engineer, M. Tresca, has recently called the attention of the Academy of Sciences to a very curious experimental locomotive now on trial on the Eastern Railway. A small model, worked with compressed air, is on exhibition in Paris. This locomotive has no wheels, but in place thereof it has legs. It does not roll then on the rails, but it walks, runs and gallops. Suppose an ordinary locomotive with straight shafts, terminated by large circular feet. Three of its legs are in front and three behind. The motor cylinders, in place of revolving the wheels, cause these large treadles to rise and fall. The treadles placed on the side are brought special action when the machine trots, those in the middle when it gallops. The whole treadle system acts like a horse with three legs, having a gait resembling an amble and a trot at the same time. Nothing can be more surprising to look at. It would almost seem as if there actually was an animal concealed in the machine, whose legs only were visible and sustained the whole. The object of this novel arrangement is said to be to reduce the dead weight of the locomotive itself, and to increase its adherence. With this machine on feet, a grade of one in ten may be ascended very readily. The locomotive being experimented with on the Eastern Railway of France weighs ten tons, and runs at a speed ordinarily of 7 to 8 kilometers (4 to 5 miles) an hour, though it can run as high as 20 kilometers (12·5 miles). This construction of a locomotive is obviously only applicable under very special circumstances. Mountain railways, special local railways, and common roads, are of course best adapted to it. It is the invention of a well-known constructor, M. Fortin Hermann.

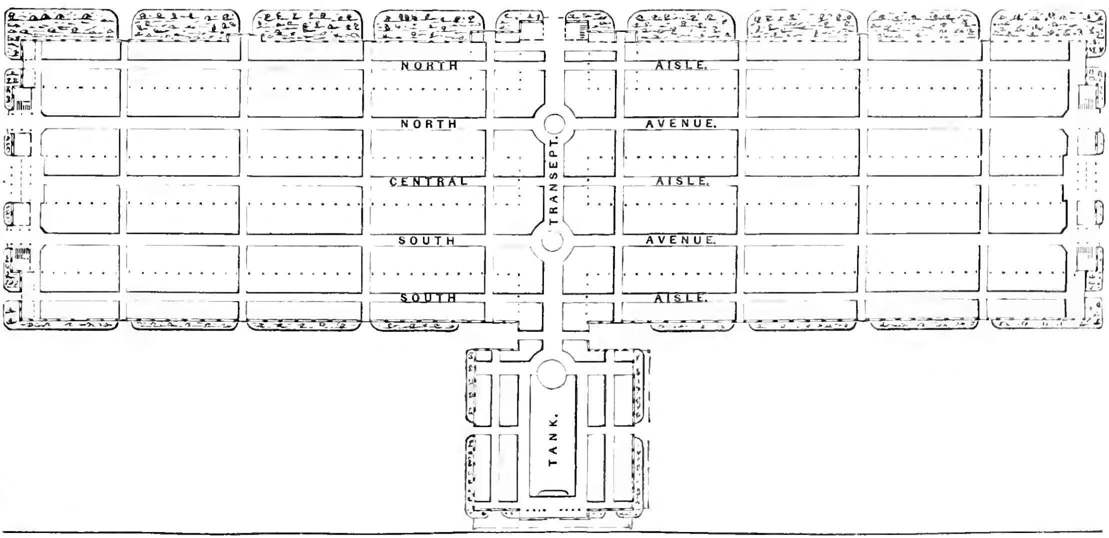
Centennial Exhibition.—We present with this issue of the JOURNAL illustrations of the Machinery Hall, showing a perspective of the complete building, with the ground plan and two sections of the frame-work, one across the main building looking towards the transept, showing half the width, and the other through the annex, showing the water tank. By reference to the situation plan in the April number and the bird's eye view of the Buildings and Grounds in the last number it will be seen that this structure is located west of the intersection of Belmont and Elm Avenues; the distance from the west front of the Main Exhibition Building, being 542 feet from the north side of Elm Avenue, 274 feet. The north front of the Building will be upon the same line as that of the Main Exhibition Building, thus presenting a frontage of 3,824 feet from the east to the west ends of the Exhibition Buildings upon the principal avenue within the grounds.

The Building consists of the Main Hall, 360 feet wide by 1,402 feet long, and an annex on the south side of 208 feet by 210 feet. The entire area covered by the Main Hall and annex is 558,440 square feet, or 12·82 acres. Including the upper floors the building provides 14 acres of floor space.

The principal portion is one story in height, showing the main cornice upon the outside at 40 feet from the ground, the interior height to the top of the ventilators in the avenues being 70 feet, and in the aisles 40 feet. To break the long lines upon the exterior, projections have been introduced upon the four sides, and the main entrances finished with facades, extending to 78 feet in height. The east entrance will form the principal approach from street-cars, from the Main Exhibition Building, and from the railroad depot. Along the south side will be placed the boiler houses and such other buildings for special kinds of machinery as may be required. The west entrance affords the most direct communication with George's Hill, which point affords the best view of the entire Exhibition grounds.

The arrangement of the ground plan shows two main avenues 90 feet wide by 1,360 feet long, with a central aisle between and an aisle on either side. Each aisle is 60 feet in width; the two avenues and three aisles making the total width of 360 feet. At the centre of the building is a transept of 90 feet in width, which at the south end is prolonged beyond the Main Hall. This transept, beginning at 36 feet from the Main Hall and extending 208 feet, is flanked on



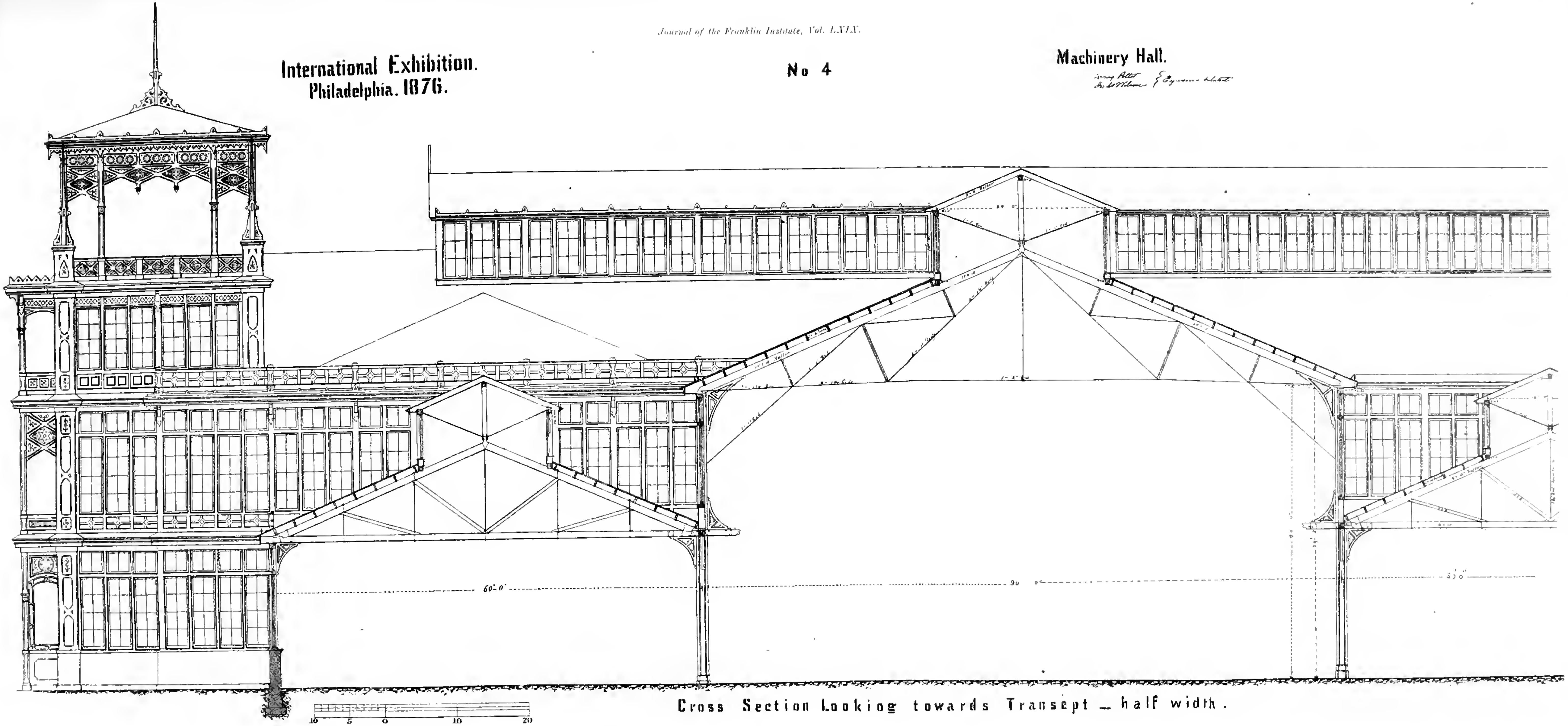


Ground Plan, Machinery Hall.

International Exhibition.
Philadelphia. 1876.

No 4

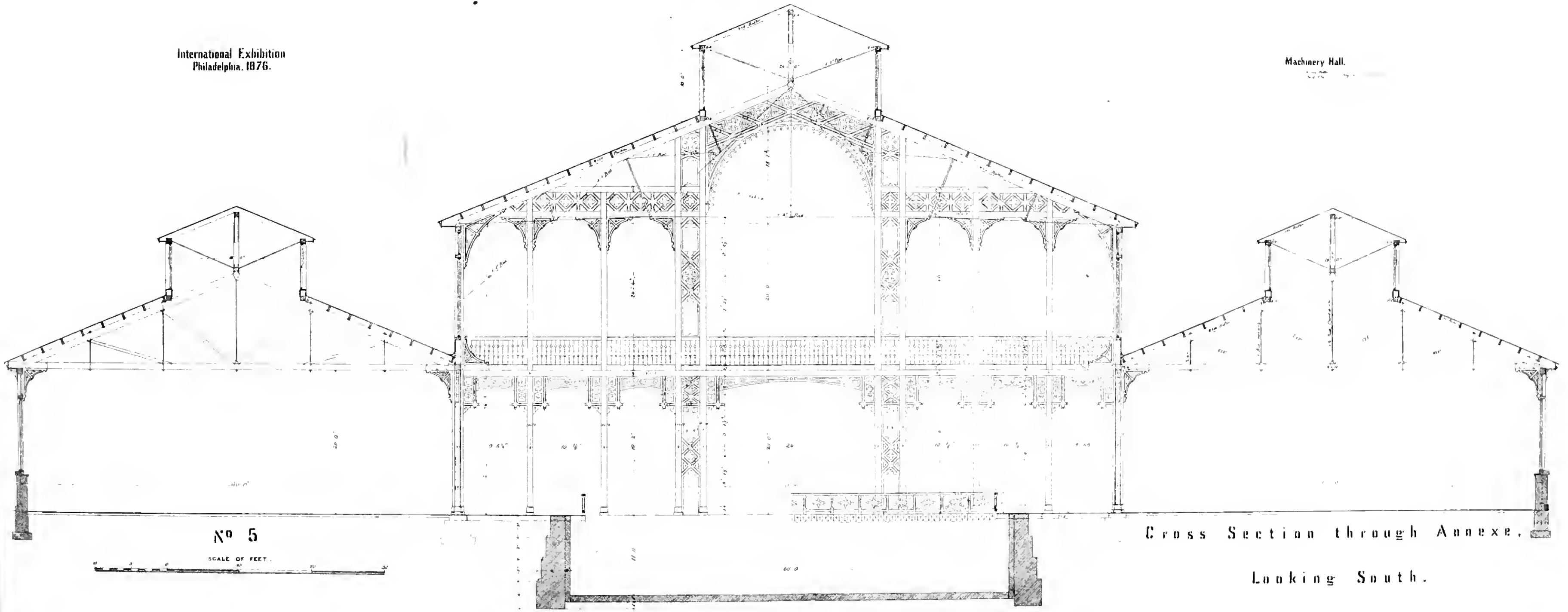
Machinery Hall.



Cross Section Looking towards Transept — half width.

International Exhibition
Philadelphia. 1876.

Machinery Hall.



No 5

SCALE OF FEET

Cross Section through Annexe,

Looking South.

either side by ...
draulic machinery. ...
width; in the ...
walks extending ...
either end to ...

The foundation ...
consists of ...
with straight ...
a general rule ...
the uniform distance ...
to the next ...
and they support ...
height of 20 feet ...
of 5 feet, and ...
the external ...
Louvre ventilation ...
avenues and the ...
stands lengthwise ...

The fad ...
superior. Eight ...
entire length of ...
the aisles ...
wooden ...
distance ...
together, one at ...

The annex for hydraulic ...
feet, depth of water ...
that hydraulic machinery ...
south end of this tank ...
wide, supplied from the ...

On either side of the ...
from which the pump ...
pipes passing directly ...

Discharge pipes leading ...
the floor, so that the pumps ...
but those pumps nearest the ...
ing directly in the tank ...

A contract ...
tence, R. I., ...

either side by aisles of 60 feet in width, and forms the annex for hydraulic machines. The promenades in the avenues are 15 feet in width; in the transept 25 feet, and in the aisles 10 feet. All other walks extending across the building are 10 feet in width, and lead at either end to exit doors.

The foundations consist of piers of masonry. The superstructure consists of solid timber columns supporting roof trusses, constructed with straight wooden principals and wrought iron ties and struts. As a general rule the columns are placed lengthwise of the building at the uniform distance apart of 16 feet. The columns are 40 feet high to the heel block of the 90 feet span roof trusses over the avenues, and they support the heel of the 60 feet spans over the aisles, at the height of 20 feet. The outer walls are built of masonry to a height of 5 feet, and above that are composed of glazed sash placed between the columns. Portions of the sash are movable for ventilation. Louvre ventilators are introduced in continuous lengths over both the avenues and the aisles. The building is lit entirely by side light, and stands lengthwise nearly east and west.

The facilities for the most complete system of shafting, are very superior. Eight main lines may be introduced, extending almost the entire length of the structure, and counter-shafts introduced into the aisles at any point. The hangers will be attached either to the wooden horizontal ties of the 60 feet span roof trusses, or to brackets especially designed for the purpose, projecting from the columns, in either case at the height of 20 feet from the floor.

The annex for hydraulic machines contains a tank 60 feet by 160 feet, depth of water of 10 feet. In connection with this it is expected that hydraulic machinery will be exhibited in full operation. At the south end of this tank will be a waterfall 35 feet high by 40 feet wide, supplied from the tank by the pumps upon exhibition.

On either side of this tank will be deep trenches connected with it, from which the pumps may take their supply of water, by means of pipes passing directly down through the floor.

Discharge pipes leading to the waterfall will also be placed under the floor, so that the pumps may make easy connection with them; but those pumps nearest the tank may have pipes overhead discharging directly in the tank, if desired.

A contract has been entered into with Mr. Geo. H. Corliss, of Providence, R. I., to furnish the steam power for the Main Hall. The engines

will be placed at the intersection of the transept with the south avenue, and will be of the following general description: One pair of beam engines, with cylinders of 46 inches diameter, 10 feet stroke, making 35 revolutions per minute and capable of being worked up to 2000 horse-power, if required.

The main shaft of these engines will run north and south, and the principal lines of shafting running east and west will be driven from it by bevel gear wheels.

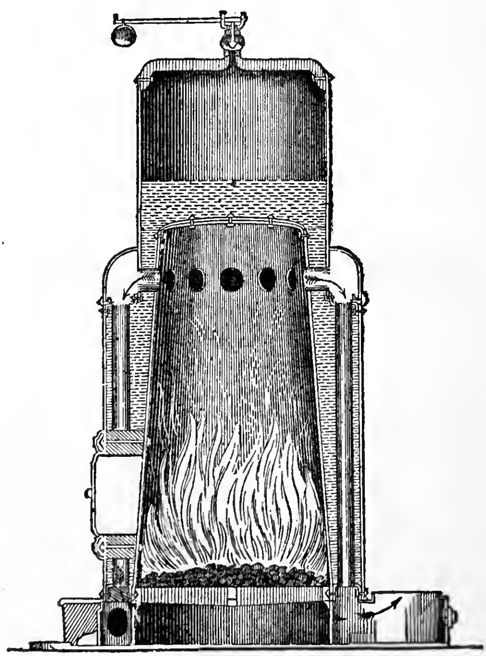
The steam will be furnished from 20 upright Corliss boilers, placed in a house at the east side of the annex.

Another engine will probably be located in the annex to drive such hydraulic machines as require belt power.

The water wheels will be located at the south end of the annex, in the immediate vicinity of the waterfall, from the head of which they will take their supply of water.

The progress on this as on the Main Building, Art Building and Horticultural Hall for the month is very encouraging. K.

The Shapley Portable Steam Engine.—One of these engines of five horse-power was loaned by Messrs. Henry Snyder & Co., and



used at the meeting of the Institute in June to drive the Gramme Magneto-Electric Machine. A similar one of eight horse-power was placed in competition at the late Exhibition, and was the only one of this class that was submitted to a thorough test, and the extract from the Report of the Judges, given below, shows its performance, which is worthy of attention.

The principal peculiarity is in the boiler, the construction of which is shown in the accompanying cut.

The engine is of the plain three port slide valve pattern, and stands upright on the base plate which supports the boiler. The exhaust steam passes through the feed-water heater on its way to the chimney. The whole is mounted on small wheels.

The following is taken from the Report of the Judges:

Total area of heating surface in square feet,	69·5
Area of grate surface " " "	3·14
Steam (pressure) per square inch, in pounds,	67
Temperature of feed-water,	177°
Diameter of cylinder,	6 in.
Stroke of piston,	10 "
Indicated horse-power,	11·35
Horse-power by Dynamometer,	10·40
Percentage of loss by friction,	·09

K.

Bibliographical Notices.

The Chemistry of Light and Photography. By Dr. Hermann Vogel, *Professor in the Royal Industrial Academy of Berlin.* International Scientific Series, Vol xiv. Small 8vo., pp. xii, 288. New York, 1875: D. Appleton & Co. In more than one respect this book is a stain upon the excellent International Scientific Series, now in course of publication. So far as the labor of the distinguished author himself is concerned, the book is in every way worthy of the position it occupies in the Series. It is clearly and lucidly written; the subject it attempts to treat is well embraced within its pages; and the matter is so well digested, and at the same

time so comprehensive, that not only will the general public, for whose instruction the Series was primarily designed, be profited by an examination of the book, but also the professional photographer cannot fail to be well repaid for an attentive perusal of its pages. Moreover, the work of the publisher, so far as the general make-up of the book is concerned, is well done, and in keeping with the other volumes of the Series. But the work of the translator is simply execrable. The rendering of the German words into English is in numberless cases incorrectly and carelessly done; the chemical and technical words are, in general, wrongly translated, and in some cases, so distorted that even a chemist would not recognize what was meant; in some places the author is made to say directly the reverse of what he intended to say; and in several instances the translator has not only failed to give us the author's meaning, but he has not even made good sense, much less good English, of what he has given us. In short, the translation is evidently job-work, cheaply done, and without the supervising eye of any competent person. And if the American publishers of the International Scientific Series intend to give us such translations as this for the remaining numbers of the Series, which are announced to appear from foreign authors, we can assure them that they will find it difficult to maintain the high character of the enterprise, which they have thus far so well carried out. But that what we have written may not appear to be all assertion, we will cite a few examples of the errors of translation referred to above. On page 19 the translator says:

"By employing *Iodide of Bromium*, and Voigtlander's lens, the process of exposure was made a matter of seconds."

Iodide of Bromium not being a common chemical, and not being mentioned in the chemical dictionaries, it became necessary to refer to the author's own words, to see whether he had really made use of such a term. By consulting a German copy of the book we find that the author, in his historical sketch of Photography, was saying that at first only iodine was used to render the daguerreotype plates sensitive to light, and that such a plate needed exposure to the light for twenty minutes. Soon it was found that bromine used along with the iodine shortened the exposure to one or two minutes, and finally the invention of a new lens and the use of Brom-iodine, (Bromiod), that is Bromine and Iodine together, as was entirely evident from the context, shortened the exposure to seconds.

Again on page 107, under the head of Operation of Light on the Elements the translator gives us the following:

"The chemist understands by the term elements, simple insoluble bodies. * * * * * The chemical elements are the well known metals, also sulphur, phosphorus, chlorine, (a greenish strong-smelling gas developed from chloride of lime); further the less known substance, bromine, (a brown unpleasantly smelling substance of a fluid nature);

lastly iodine, (a black substance also of a fluid nature and used for friction). All these elements unite together and produce bodies with new properties. * * * * * Sulphur unites with oxygen and produces the pungent strong-smelling sulphuric acid."

That the distinguished author of the book, Dr. Vogel, would not make so many mistakes in the space of half a page seems more than probable, and so we consult our German copy again and find that what he really did say is: "The chemist understands by the term elements, simple undecomposable bodies. * * * * * * All the well-known metals are elements, likewise sulphur, phosphorus, chlorine, (the greenish unpleasantly smelling gas which rises from chloride of lime; further the less known substance bromine, a brown stinking fluid), and the black volatile iodine which is used in embrocations. All these elements combine one with another and produce bodies with entirely new properties. * * * * * Sulphur combines with oxygen and produces the pungent, strong-smelling sulphurous acid." All, even those not chemists, will recognize the magnitude of the mistake in the last sentence when we say that sulphurous acid is the suffocating gas which arises when a sulphur match is burned, and that sulphuric acid is the quiet, heavy liquid commonly known as oil of vitriol.

Again, on page 111, when speaking of the decomposition of chloride of silver by the action of light, the translator makes the author say:

"The chloride is liberated and disappears partly as a greenish gas which, from its abundance as well as its odor, can be perceived to be chloride of silver."

What the author did say was: "The chlorine becomes free and disappears partially, as a greenish gas, which in case the amount of chloride of silver is large may be recognized even by the smell."

Again in the following page the translator says:

"We have previously seen in treating of the practical part of photography that plates of iodide of silver and of chloride of silver are exposed in the camera."

But the author says: "We have seen above, in speaking of the practical part of photography that it is not chloride of silver but iodide of silver plates which are exposed to the action of light in the camera obscura."

Still further, in speaking of the use of photography in the determination of the sun's distance by the Transit of Venus method, the translator says:

"But Venus is not visible at the moment when it is placed before the sun's disk."

Whereas, on the contrary, the author says: "On such an occasion, (that is when Venus is between the sun and the earth) Venus is only visible when it is directly before the sun's disk."

Again, on page 222, the translator gives us the following curious chemical transformation:

"The last combination, chromic acid (the author had been enumerating the combinations of chromium with oxygen), is the best known of all; on adding to it sulphuric acid it changes to chromate of potash and crystallizes into red needles which easily lose part of its oxygen."

But the author is not so faulty in his chemistry as this. His statement is: "The latter combination, chromic acid, is the best known of all; it separates, on the addition of sulphuric acid to chromate of potash, and crystallizes in red needles which very easily lose part of their oxygen."

On the following page too the translator makes use of the following singular sentence:

"Chromic acid is of special interest in the object that engages it because both it and its salts are sensitive to light."

But the author says: "In reference to our subject (*i.e.*, photography) chromic acid is of especial interest, inasmuch as both it and its salts are sensitive to light."

And thus we might go on and cite numerous errors of smaller importance, but perhaps we have given enough to show that the translation is worthless. And the proof-reading is not much better. We have purposely omitted, in what we have given above, citing any error which by any means might be attributed to the proof-reader, but it was not for want of material. There are scarce a dozen pages together throughout the book which are not disfigured by errors that a careful proof-reader would detect. In short, the book in its present form is a disgrace to the publishers who have sent it out, and a decent regard for their own reputation and the rights of the public would seem to demand that they should recall the present edition and issue another after the book shall have passed under the eye of some competent person. D.

Franklin Institute.

Hall of the Institute, May 19th, 1875.

The stated meeting of the Institute was called to order at 8 o'clock, P.M., Vice-President Charles S. Close in the chair.

There were 125 members present.

The minutes of the stated meeting for April were read and approved.

The Actuary presented the minutes of the Board of Managers and reported that at their meeting held on the 12th instant they had, in accordance with the recommendation of the Committee on Science and the Arts, awarded the Scott Legacy Medal and Premium to Thomas J. Rorer, for the "Improved Union Belting," patented by Clark & Flemmer; and the Elliott Cresson Gold Medal to Powers & Weightman, for their manufacture of Citric Acid, and the cheaper alkaloids of Cinchona Bark. Also that there were ten persons elected members of the Institute, and the following donations made to the Library.

Pennsylvania Archives. Second series. Published under direction of Matthew S. Quay, Secretary of the Commonwealth. Edited by John B. Linn and Wm. H. Egle, M.D. Vol. I. Harrisburg, 1874. From the Secretary of the Commonwealth.

The Use of the Steam Engine Indicator; or, Practical Science for Practical Men. By Edward Lyman, C.E., 1874. From the Author.

Statistical Report on the Sickness and Mortality in the Army of the United States. From the Surgeon General U. S. A.

Meteorological Register for Twelve Years, from 1831 to 1842 inclusive. From the Surgeon General U. S. A.

Circular No. 1. Report on Epidemic Cholera and Yellow Fever in the Army of the United States during the year 1867. From the Surgeon General U. S. A.

Statistical Report on the Sickness and Mortality in the Army of the United States, 1860. From the Surgeon General U. S. A.

Statistical Report on the Sickness and Mortality in the Army of the United States. Washington, 1856. From the Surgeon General U. S. A.

Catalogue of the Library of the Surgeon General's Office, U. S A. Washington, 1873. From the Surgeon General U. S. A.

Catalogue of the Medical Section of the United States Army Medical Museum. Washington, 1867. From the Surgeon General U. S. A.

Catalogue of the Surgical Section of the United States Army Medical Museum. Washington, 1866. From the Surgeon General U. S. A.

The Secretary reported that the Committee on Science and the Arts have changed the day of holding the stated meetings, from the third Monday, to the first Wednesday of each month.

The Committee on Plans for the alteration of the Institute Building reported progress.

The Secretary presented his report on Mechanical Novelties, etc., embracing a new Grate-bar Cleaner, the invention of Wm. M. Perrins; a Pocket-book Holder, the invention of Geo. S. Knapp, of Chicago; a Rotary Pressure Blower, the invention of Thos. S. Disston; Merriman's Waterproof Life-Saving Dress, being a duplicate of the one used by Boyton, in his recent passage of the English Channel.

A comparison of Gas Microscopes was then made by Mr. D. S. Holman, using his instrument made by Joseph Zentmayer, of this city, and Messrs. Queen & Co., one made by themselves.

Mr. Holman also exhibited and explained a new arrangement of Diaphragm, to be attached to the tube of the objective of Gas Microscopes, consisting of a rotating disk, with several apertures of different sizes to suit different objects, and placed immediately in front of the object and in the focus of the lens.

The Secretary then projected on the screen a number of views showing the progress on the Centennial Buildings, and also views of the Fairmount and Girard Avenue Bridges.

The proposed amendments to the By-Laws, offered at the stated meeting in April, and postponed to this meeting, came up for discussion, and on motion of Mr. Hoover, they were laid on the table by a vote of 71 ayes, to 11 nays.

Mr. J. E. Mitchell offered the following resolution, which on being put to a vote, was lost:

Resolved, that postal card notices of the next meeting of the Institute be sent to all members in good standing, and thereafter to all those who shall have attended any of the three stated meetings immediately preceding it, to all the officers and members of standing committees and to such others as may desire to have their names added to the notice list. Provided that no member shall be entitled to such notice when six consecutive stated meetings shall have passed without his having attended any of them.

Mr. J. J. Weaver offered the following resolution, which was adopted by 65 ayes, to 17 nays:

Resolved, that hereafter all members in good standing be notified of the meetings of the Institute, by postal card, stating the nature of the business to be brought before it.

On motion the meeting then adjourned.

J. B. Knight, *Secretary.*

Civil and Mechanical Engineering.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

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[Continued from Vol. lxix, page 349.]

Explanation of tables 1 *to* 6, *both inclusive, containing the data and results of the experiments made with screws A, B, C, D, E, F, G, and H, to determine their relative economic efficiencies.*

In the following tables, numbered 1 to 6, both inclusive, will be found the data and results of all the experiments made with screws, A, B, C, D, E, F, G, and H, to determine their relative economic efficiencies when applied to the propulsion of steam-launch No. 4. For facility of reference, the lines containing the quantities are numbered and arranged in groups; and the columns containing the data and results for the different speeds of vessel at which the experiments were made are lettered.

These quantities were obtained, for each screw, in the following manner, namely:

On a straight line, taken for a base, all the experimental speeds of the vessel were laid off by scale as abscissæ, and on ordinates erected from these abscissæ, at right angles to the base, were laid off, by scale, the corresponding experimental slips of the screw. A fair curve was then passed through the ends of these ordinates, dividing them as equally as possible. Finally, there were laid off, by scale on the base, abscissæ representing the speeds of vessel given in line 1 of the table; and from these abscissæ right-angled ordinates were erected until they cut the curve, and on them were measured by scale, the distances be-

tween the curve and the base, which distances gave the true slips of the screw, as shown in line 2 of the tables, and corresponding to the speeds of vessel shown in line 1. The speeds in line 1 are given in geographical miles of 6,086 feet per hour, increasing for each column of the tables by one-half a geographical mile per hour, commencing in column *a* with 5·0 geographical miles per hour, and ending in column *h* with 8·5 geographical miles. The slip of the screw is expressed in per centum of its speed; the latter being measured by the product of its pitch and of the number of its revolutions made in a given time. The speed of the vessel in the same terms being deducted from the speed of the screw thus obtained, the remainder, expressed in per centum of the latter, is the quantity on line 2. In screws G and H, having expanding pitches in the direction of their axes, the mean pitch is used in all calculations.

From the quantities on lines 1 and 2, that on line 5 is calculated in the following manner:

Let—

A = speed of vessel in feet per hour, (line 1).
B = slip of the screw in per centum of its speed, (line 2).
C = pitch of the screw in feet.

Then—

$$\frac{A \div 1 - B}{C \times 1440} = \text{The number of double strokes of engines' piston,}$$

and of revolutions of the screw, made per minute, given on line 5.

The quantities on lines 6 to 12, both inclusive, grouped under the head of "Distribution of the indicated pressure on the pistons," are obtained from the indicator-diagrams in the following manner:

These diagrams were taken as rapidly as possible by expert assistants from each end of each cylinder; and the average mean pressure from all of them for each experiment ascertained. From this mean pressure and the average experimental number of double strokes of engines' pistons made per minute during the experiment, was calculated the gross effective horse-powers developed, during the experiment, by the engines. The distribution of this power, for each experiment, was then determined as follows: taking, for example, the

experiment in table No. 1, column *a*, in which the gross effective horse-powers developed by the engines, (line 13) was 6·6847.

The pressure required to work the engines and shafting, being, by direct experiment, 2 pounds per square inch of piston, (line 7), and constant for all speeds, the power thus absorbed is (line 14) 0·6109 horse.

Deducting from the gross effective power of 6·6847 horses developed by the engines, this power of 0·6109 horse, there remains the net power of 6·0738 horses (line 15) applied to the shaft, of which $7\frac{1}{2}$ per centum, or 0·4555 horse (line 16) is absorbed by the friction of the load.

The power expended in overcoming the cohesive resistance of the water by the screw-blades, calculated in the ratio of the square of the velocity, and for a value of 0·45 pound avoirdupois per square foot of helicoidal surface moving in its helical path with a velocity of 10 feet per second, amounts to 0 3598 horse (line 17).

The powers (0·4555 and 0·3598 horse) absorbed by the friction of the load and expended in overcoming the cohesive resistance of the water by the screw-blades, being deducted from the power (6·0738 horses) applied to the shaft, there remains 5·2585 horse-powers expended in the slip of the screw and in the propulsion of the hull. And as the slip of the screw is 7.82 per centum of its speed (line 2), the power expended in it is $(5{\cdot}2585 \times {\cdot}0782) = 0{\cdot}4112$ horse (line 18), leaving $(5{\cdot}2585 - 0{\cdot}4112) = 4{\cdot}8473$ horses (line 19) expended in the propulsion of the simple hull.

The quantity on line 19 is the same as that on line 4, and from it the thrust of the screw in pounds can easily be calculated.

Let A = the number of horse-powers expended in the propulsion of the simple hull.

B = the speed of the vessel in feet per minute.

Then

$$\frac{A \times 33000}{B} = \text{the thrust of the screw in pounds.}$$

In this manner the quantity on line 3 is calculated from that on line 4 or line 19 for the speeds of vessel in the different columns of the tables.

The quantities on lines 20, 21, 22 and 23 are simply the per centum which the quantities on lines 16, 17, 18 and 19 are respectively of the quantity on line 15.

The quantities on lines 6 to 12, both inclusive, are calculated respectively from the quantities on lines 13 to 19, both inclusive, using the areas of the pistons, and the speed of piston in feet per minute deduced from the quantity on line 5.

During the entire time of each experiment a dynamometer-diagram was taken, and the mean pressure obtained from it and multiplied by the leverage of the instrument is the same as found on line 3. From this pressure the quantity on line 4 is obtained by multiplying it by the speed of the vessel in feet per minute and dividing by 33,000.

The difference between the thrusts of the screws, as given directly by the dynamometer, and indirectly by the indicator, was very small, as will be seen from the fact that their sum by the dynamometer was 22,142, and by the indicator 22,203, the difference of which is only 0·275 per centum of the larger quantity.

After the experimental thrusts of all the screws in all the experiments were ascertained, both directly by the dynamometer and indirectly by the indicator, as above described, for the experimental speeds of the vessel, the latter were laid off by scale on a straight base-line as abscissæ. From these abscissæ right-angled ordinates were erected, on which the corresponding experimental thrusts of the screws were laid off by scale, and a fair curve passed among their ends so as to equally divide them, leaving as many on one side the curve as on the other. Then there were laid off by scale on the base, abscissæ representing the speeds of the vessel given in line 1 of the tables; and from these abscissæ right-angled ordinates were erected until they cut the curve, and on them were measured by scale the distances between the curve and the base, which distances gave the true thrusts of the screw, as shown on line 3 of the tables, and corresponding to the speeds of vessel shown on line 1. These thrusts are expressed in pounds avoirdupois.

Table No. 1, containing the results of the experiments made with screws A, E, and F, all having the same diameter, 4⅓ feet; the same uniform pitch, 5·130 feet; the same fraction of the pitch, 0·5370, and the same quantity and kind of surface, but differing in the number and arrangement of the blades. Screw A has two blades, one directly opposite the othe.; screw E has four blades, in two pairs, at right angles to each other; and screw F is a Mangin screw, with two pairs of directly opposite blades, one pa r immediately behind the other.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	7·82	8·37	8·87	9·40	10·10	11·56	13·33	14·57
3	Thrust of the screw, in pounds, by dynamometer	315·4	308·8	449·9	560·6	707·0	807·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8173	6·2348	8·2972	11·2004	15·2110	19·9893	24·3012	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	107·1247	118·5443	130·0306	141·6905	153·7779	167·4820	182·2959	196·5007
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·8838	25·3212	30·4249	37·3312	40·3393	56·2773	64·1455	70·1537
7	Pressure required to work the engines, *per se*, in pounds per sq. inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·8838	23·3212	28·4249	35·3312	44·3393	54·2773	62·1455	68·1537
9	Pressure absorbed by the friction of the load, in pounds per sq. inch of pistons	1·4913	1·7491	2·1319	2·6498	2·3254	4·0708	4·6609	5·1115
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	1·1771	1·4436	1·7368	2·0598	2·4298	2·8767	3·4118	3·9665
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	1·3161	1·6838	2·1773	2·8972	3·8974	5·4712	7·2089	8·6078
12	Pressure expended in the propulsion of the vessel, in lbs. per sq. inch of pistons	15·8693	18·4447	22·3789	27·7244	34·6867	41·8586	46·8639	50·4679
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·0847	8·5592	11·2803	15·0828	20·3195	26·8764	33·3436	39·3083
14	Horse-powers expended in working the engines, *per se*	0·6109	0·6761	0·7416	0·8081	0·8770	0·9551	1·0396	1·1206
15	Net horse-powers applied to the shaft	6·0738	7·8831	10·5387	14·2747	19·4425	25·9213	32·3040	38·1877
16	Horse-powers absorbed by the friction of the load	0·4555	0·5912	0·7904	1·0706	1·4582	1·9441	2·4228	2·8641
17	Horse-powers expended in overcoming the resistance of the water, by the screw-blades	0·3598	0·4876	0·6435	0·8320	1·0644	1·3751	1·7732	2·2209
18	Horse-powers expended in the slip of the screw	0·411	0·5695	0·8076	1·1711	1·7059	2·6128	3·7468	4·8231
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3012	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-blades	5·92	6·19	6·11	5·83	5·48	5·30	5·49	5·82
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	6·77	7·22	7·66	8·20	8·79	10·08	11·60	12·63
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	79·81	79·09	78·73	78·47	78·23	77·12	7 ·41	74·05

Table No. 2, containing the results of the experiments made with screw B, having the diameter 4⅓ feet, the uniform pitch 5·136 feet, two blades directly opposite each other, and the fraction of the pitch 0·2799.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	8·74	9·35	9·90	10·49	11·26	12·83	14·81	10·15
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	108·2083	119·8272	131·5220	143·4137	155·7867	169·9860	185·4624	200·2043
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·4659	24·8112	29·8120	36·5831	45·4897	55·2601	62·9728	68·8945
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·4659	22·8112	27·8120	34·5831	43·4897	53·2601	60·9728	66·8945
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	1·4599	1·7108	2·0859	2·5937	3·2617	3·9945	4·5730	5·0171
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	0·7903	0·9718	1·1681	1·3902	1·6396	1·9546	2·3292	2·8029
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	1·5047	1·8819	2·4335	3·2093	4·3446	6·0717	8·0057	9·5392
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	15·7110	18·2467	22·1245	27·3899	34·2438	41·2393	46·0649	49·5353
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·6234	8·4776	11·1805	14·9603	20·2075	26·7852	33·3026	39·3303
14	Horse-powers expended in working the engines, *per se*	0·6171	0·6834	0·7501	0·8179	0·8884	0·9394	1·0577	1·1420
15	Net horse-powers applied to the shaft	6·0063	7·7942	10·4304	14·1424	19·3191	25·8158	32·2449	38·1883
16	Horse-powers absorbed by the friction of the load	0·4505	0·5845	0·7823	1·0606	1·4489	1·9362	2·4184	2·8641
17	Horse-powers expended in overcoming the resistance of the water, by the screw-blades	0·2443	0·3318	0·4387	0·5688	0·7291	0·9472	1·2302	1·5978
18	Horse-powers expended in the slip of the screw	0·4642	0·6431	0·9122	1·3123	1·9301	2·9431	4·2351	5·4468
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw blades	4·06	4·23	4·20	4·02	3·77	3·67	3·82	4·19
22	Per centum of the net power applied to the shaft expended in the slip of the screw	7·73	8·25	8·75	9·28	9·99	11·40	13·13	14·26
23	Per centum of the net power applied to the shaft expended in the propulsion of the vessel	80·71	79·99	79·55	79·20	78·74	77·43	75·55	74·05

Table No. 3, containing the results of the experiments made with screw C, having the diameter $4\frac{1}{3}$ feet, the uniform pitch 5·133 feet, two blades directly opposite each other, and the fraction of the pitch 0·1785.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,080 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	10·43	11·16	11·83	12·54	13·47	15·42	17·78	19·43
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	110·2455	122·4942	134·3952	146·7752	159·7246	175·1186	192·2588	208·3610
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·2074	24·5542	29·5884	36·2747	45·1418	54·8683	62·4379	68·2274
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·2074	22·5542	27·5884	34·2747	43·1418	52·8683	60·4379	66·2274
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	1·4406	1·6916	2·0691	2·7206	3·2356	3·9651	4·5328	4·9670
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	0·6204	0·7714	0·9297	1·1717	1·3115	1·5755	1·8977	2·2252
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	1·7882	2·2419	2·9078	4·0591	5·1986	7·2958	9·5734	11·4706
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	15·3582	17·8493	21·6818	23·3233	33·3961	40·0319	44·4340	47·5646
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·6912	8·5765	11·3239	15·1319	20·5298	27·3383	34·2298	40·5649
14	Horse-powers expended in working the engines, *per se*	0·6287	0·6986	0·7664	0·8370	0·9109	0·9387	1·0964	1·1883
15	Net horse-powers applied to the shaft	6·0625	7·8779	10·5575	14·3449	19·6189	26·3996	33·1334	39·3766
16	Horse-powers absorbed by the friction of the load	0·4547	0·5908	0·7918	1·0759	1·4737	1·9800	2·4850	2·9532
17	Horse-powers expended in overcoming the resistance of the water, by the screw-blades	0·1961	0·2691	0·3553	0·4628	0·5964	0·7860	1·0401	1·3239
18	Horse-powers expended in the slip of the screw	0·5644	0·7832	1·1132	1·6058	2·3678	3·6443	5·2471	6·8199
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-blades	3·23	3·42	3·37	3·23	3·04	2·93	3·14	3·36
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	9·31	9·94	10·54	11·19	12·05	13·80	15·81	17·32
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	79·96	79·14	78·59	78·08	77·41	75·72	73·52	71·82

Table No. 4, containing the results of the experiments made with screw D, having the diameter 4⅓ feet, the uniform pitch 5·136 feet, two blades directly opposite each other, and the fraction of the pitch 0·1014.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	13·01	13·93	14·76	15·64	16 80	19·83	22·18	24·24
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	113·5172	126·2550	139·0130	151·8217	166·1714	183·3535	203·0254	221·0284
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·0166	24·2691	29·1565	35·8818	44·5813	54·2337	61·7576	67·5689
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·0166	22·2691	27·1565	33·8818	42·5813	52·2337	59·7576	65·5689
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	1·4262	1·6702	2·0367	2·5411	3·1936	3·9175	4·4818	4·9177
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	0·3765	0·4654	0·5649	0·6709	0·8048	0·9820	1·2011	1·3901
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	2·2402	2·8037	3·6254	4·7977	6·4809	9·1043	11·9933	14·0317
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	14·9737	17·3298	20·9295	25·8721	32·1020	38·2299	42·0814	45·2294
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·8029	8·7372	11·5574	15·5338	21·1241	28 3549	35·7528	42·5858
14	Horse-powers expended in working the engines, *per se*	0·6474	0·7250	0·7928	0·8658	0·9467	1·0457	1·1578	1·2605
15	Net horse-powers applied to the shaft	6·1555	8·0122	10·7646	14·6680	20·1774	27·3092	34·5950	41·3253
16	Horse-powers absorbed by the friction of the load	0·4617	0·6009	0·8073	1·1001	1·5133	2·0482	2·5946	3·0994
17	Horse-powers expended in overcoming the cohesive resistance of the water by the screw blades	0·1216	0·1674	0·2234	0·2910	0·3816	0·5126	0·6959	0·8980
18	Horse-powers expended in the slip of the screw	0·7249	1·0091	1·4367	2·0765	3·0715	4·7591	6·9433	9·0483
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water, by the screw blades	1·98	2·09	2·08	1·98	1·89	1 88	2·01	2·12
22	Per centum of the net power applied to the shaft expended in the slip of the screw	11·78	12·59	13·35	14·16	15·22	17·43	20·07	21·40
23	Per centum of the net power applied to the shaft expended in the propulsion of the vessel	78·74	77·82	77·07	76·36	75·39	73·19	70·42	68·43

Table No. 5, containing the results of the experiments made with screw G, having the diameter 4⅓ feet, a pitch expanding in the direction of the axis from 6½ feet to 7½ feet, three blades, and the fraction of the pitch 0·3446.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,080 feet	5·0	5·5	6·0	6·5	7 0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed calculated for its mean pitch	9·89	10·58	11·22	11·89	12·77	14·63	16·89	18·48
3	Thrust of the screw, in pounds, by dynamometer	315·4	368 8	449 9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4 8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	80·4029	89 1264	97·9321	106·9028	116·2882	127·3085	139·4847	151·0832
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	29·5351	34·3263	41·2660	50·7584	63·2041	76·9494	87·9421	96·4132
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	27·5351	32·3263	39·2660	48·7584	61·2041	74·9494	85·9421	94·4132
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	2·0651	2·4245	2·9449	3·6569	4·5903	5·6212	6·4457	7·0810
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	2·0068	2·4663	2·8537	3·4006	4·0260	4·8276	5·8003	6·8088
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	2 3205	2·9027	3·7550	4·9582	6·7155	9·4364	12·4473	14·8807
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	21·1427	24·5328	29·7124	36·7427	45·8723	55·0642	61·2488	65·6427
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·7714	8·7238	11·5236	15·4728	20·9581	27·9340	34·9780	41·5359
14	Horse-powers expended in working the engines, *per se*	0·4585	0·5083	0·5585	0·6097	0·6632	0·7260	0·7955	0·8616
15	Net horse-powers applied to the shaft	6·3129	8·2155	10·9651	14·8631	20·2949	27·2080	34·1825	40·6743
16	Horse-powers absorbed by the friction of the load	0·4735	0·6162	0·8224	1·1147	1·5221	2·0406	2·5637	3·0506
17	Horse-powers expended in overcoming the cohesive resistance of the water, by the screw blades	0·4601	0·6268	0·7969	1·0366	1·3350	1·7525	2·3070	2·9333
18	Horse-powers expended in the slip of the screw	0·5320	0·7377	1·0486	1·5114	2·2268	3·4256	4·9506	6·4108
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-blades	7·29	7·63	7·27	6·97	6·58	6·44	6·75	7·21
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	8·43	8·98	9·56	10·17	10·97	12·59	14·48	15·76
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	76·78	75·89	75·67	75·36	74·95	73·47	71·27	69·53

Table No. 6, containing the results of the experiments made with the Griffith screw H, having the diameter, 4⅓ feet; a pitch expanding in the direction of the axis from 6⅔ feet to 7⅓ feet, three blades, and the fraction of the pitch 0·2034.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed, calculated for its mean pitch	11·60	12·44	13·20	14·01	15·08	17·31	20·06	21·99
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	81·9597	91·0206	100·1646	109·5338	119·4457	131·4289	145·0135	157·9068
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	28·8521	33·4934	40·4021	49·7401	62·0121	75·5576	86·3277	94·5013
7	Pressure required to work the engines, *per se*, per sq. inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	26·8521	31·4934	38·4021	47·7401	60·0121	73·5576	84·3277	92·5013
9	Pressure absorbed by the friction of the load, in pounds per sq. inch of pistons	2·0139	2·3620	2·8802	3·5805	4·5009	5·5168	6·3246	6·9376
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	1·3752	1·6964	2·0541	2·4567	2·9208	3·5371	4·3052	5·0530
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	2·7217	3·4129	4·4177	5·8426	7·9306	11·1656	14·7838	17·7043
12	Pressure expended in the propulsion of the vessel, in lbs. per sq. inch of pistons	20·7413	24·0221	29·0501	35·8603	44·6598	53·3381	58·9141	62·8064
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·7429	8·6930	11·5395	15·5355	21·1211	28·3164	35·6967	42·5508
14	Horse-powers expended in working the engines, *per se*	0·4674	0·5191	0·5712	0·6247	0·6812	0·7495	0·8270	0·9005
15	Net horse-powers applied to the shaft	6·2755	8·1739	10·9683	14·9108	20·4399	27·5669	34·8697	41·6503
16	Horse-powers absorbed by the friction of the load	0·4707	0·6130	0·8226	1·1183	1·5330	2·0675	2·6152	3·1238
17	Horse-powers expended in overcoming the cohesive resistance of the water, by the screw-blades	0·3214	0·4403	0·5867	0·7673	0·9948	1·3256	1·7802	2·2752
18	Horse-powers expended in the slip of the screw	0·6361	0·8858	1·2618	1·8248	2·7011	4·1845	6·1131	7·9717
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-blades	5·12	5·39	5·35	5·15	4·86	4·81	5·10	5·46
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	10·14	10·83	11·50	12·24	13·22	15·18	17·53	19·14
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	77·24	76·28	75·65	75·11	74·42	72·51	69·87	68·00

DISCUSSION OF THE RESULTS OF THE EXPERIMENTS IN THE PRECEDING TABLES.

Of the resistance of the hull at different speeds.—In the following table will be found the experimental resistances of the hull in pounds, for speeds varying by 0·1 geographical mile per hour between the speeds of 5·0 and 8·5 geographical miles per hour, both inclusive, and the ratio of these resistances as compared with the ratio of the squares of the respective speeds:

Speeds of the vessel in geographical miles per hour.	Squares of the speeds of the vessel, proportionally.	Resistances of the vessel at the different speeds.		Speeds of the vessel in geographical miles per hour.	Squares of the speeds of the vessel, proportionally.	Resistances of the vessel at the different speeds.	
		In pounds avoirdupois.	Proportionally.			In pounds avoirdupois.	Proportionally.
5·0	1·0000	315·4	1·0000	6·8	1·8496	644·7	2·0441
5·1	1·0404	323·3	1·0250	6·9	1·9044	676·3	2·1443
5·2	1·0816	333·2	1·0564	7·0	1·9600	707·0	2·2416
5·3	1·1236	344·1	1·0910	7 1	2·0164	739·6	2·3450
5·4	1·1664	356·0	1·1287	7·2	2·0736	773·2	2·4515
5·5	1·2100	368·8	1·1693	7·3	2·1316	805·8	2·5549
5·6	1·2544	380·7	1·2070	7·4	2·1904	836·5	2·6522
5·7	1·2996	397·5	1·2603	7·5	2·2500	867·1	2·7492
5·8	1·3456	414·3	1·3136	7·6	2·3104	895·8	2 8402
5·9	1·3924	431·1	1·3668	7·7	2·3716	920·5	2·9185
6·0	1·4400	449·9	1·4264	7·8	2·4336	946·3	3·0003
6·1	1·4884	470·7	1·4924	7·9	2·4964	967·0	3·0659
6·2	1·5376	490·4	1·5548	8·0	2·5600	990·8	3·1414
6·3	1·5876	513·2	1·6271	8·1	2·6244	1009·5	3·2007
6·4	1·6384	536·9	1·7023	8·2	2·6896	1027·3	3·2571
6·5	1·6900	560·6	1·7774	8·3	2·7556	1043·2	3·3076
6·6	1·7424	587·3	1·8621	8·4	2·8224	1057·0	3·3513
6·7	1·7956	616·0	1·9531	8·5	2·8900	1082·4	3·4318

During the experiments, it was remarked that the vessel's "trim," or her relative draught of water forward and aft, varied with every variation of speed, the bow rising and the stern falling as the speed increased. At the maximum speeds, the variation of the draught of water forward and aft was excessive. By this continual change or trim as the speed changed, the immersed solid of the hull was continually changing in form. Strictly, there was a succession of vessels, instead of the same vessel, at different speeds; and the resistances in the above table show, in reality, not the resistance of the same immersed solid at different speeds, but the resistances of immersed solids differing more or less from each other with every change of speed. The results of the experiments show that the resistance of these dif-

ferent immersed solids varied widely from the law of its proportionality to the squar es of their speeds, increasing with increased speed sometimes less rapidly and sometimes more rapidly than due to that law, according as the actual immersed solid varied more or less favorably in function of resistance. To show this effect quantitatively, there has been placed in the following table, opposite the column of the vessel's speed, another containing the amount by which the resistance varied from the law of the squares, that amount being expressed in per centum of what the resistance would have been according to the law of its proportionality to the squares of the speeds. The prefixes of minus and plus indicate, respectively, whether the variation was less or more than the law:

Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.	Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.	Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.	Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.
5·0	....	5·9	—1·84	6·8	+ 9·51	7·7	+23·06
5·1	—1·48	6·0	—0·94	6·9	+11·19	7·8	+23·29
5·2	—2·33	6·1	+0·27	7·0	+14·37	7·9	+22·81
5·3	—2 90	6·2	+1·12	7·1	+16·29	8·0	+22·71
5·4	—3·23	6·3	+2·49	7·2	+18·22	8·1	+21·96
5·5	—3·36	6·4	+3·75	7·3	+19·86	8.2	+21·10
5·6	—3·78	6·5	+5·17	7·4	+21·08	8·3	+20·03
5·7	—3·02	6·6	+6·43	7·5	+22·19	8·4	+18·74
5·8	—2·38	6·7	+8·07	7·6	+22·93	8·5	+18·75

From the above table it will be seen that the variation of the resistance of the hull from the law of its proportionality to the squares of the speeds was irregular in quantity, alternately increasing and decreasing. From the speed of 5·0 geographical miles per hour to that of between 6·0 and 6·1 geographical miles, the resistance varied in a lower ratio than that of the squares of the speeds, the ratio slowly decreasing until, at the speed of 5·6 geographical miles per hour, it was 3·78 per centum less than was due to the law. From the speed of 5·6 geographical miles per hour to that of between 6·0 and 6·1 geographical miles, the ratio slowly increased until, at the speed of between 6·0 and 6·1 geographical miles, the resistance was in exact

accord with the law. From the latter speed, the resistance rapidly increased above that due to the law, up to the speed of 7·8 geographical miles per hour, where it was 23·29 per centum greater than was due to the law. From the speed of 7·8 geographical miles per hour, the variation from the law decreased until, at the speed of 8·5 geographical miles, the resistance was 18·75 per centum greater than was due to the law.

Components of the resistance of the hull.—The power applied to the propulsion of the hull is divided between effecting the displacement of the water, that is to say, scooping out the watery furrow or trench measured by the area of the vessel's greatest immersed transverse section and the distance run, and overcoming the friction of the immersed external surface of the vessel on the water. If we suppose that surface to have remained constant during the experiments, which was very nearly the case, its frictional resistance can be calculated for every variation of speed. It will be, in fact, in the ratio of the squares of the speeds; and, by deducting it from the experimental resistance of the vessel, the remainder will be the resistance of the immersed solid of the hull in function of form. The calculation of this frictional resistance with exactness is impossible, on account of the continuously varying curvature of the immersed surface of the hull. The speed of this surface relatively to the water in contact with it, is nowhere as great as the vessel's speed, except for the keel and other flat sufaces parallel thereto. An approximation, however, can be made by considering the speed of the surface relatively to the water in contact with it to be less than the speed of the vessel, in the ratio of the base to the hypothenuse of a right-angled triangle whose base is represented by the half length of the water-line, and whose height is represented by the half breadth of the water-line. The resistance of a square foot of the immersed surface, moving with the velocity of 10 feet per second, will be taken at 0·45 pound, and to vary as the squares of the speeds. Applying this data, the speed of the surface is 8·26 feet per second when the speed of the vessel is 5·0 geographical miles per hour; hence the resistance of the 717 square feet of immersed surface of the hull, at that speed, is $\left(\frac{717 \times 0{\cdot}45 \times 8{\cdot}26^2}{10^2}\right) = 220{\cdot}14$ pounds.

(To be continued.)

ON THE MACHINERY OF THE VIENNA EXPOSITION.

By M. Tresca.

[Editorial Note.—The French Government printing house has just issued the first four volumes of the Reports upon the Vienna Exhibition made by the members of the international jury from France. These volumes contain fifty-two reports upon various branches of knowledge, most of them by men of distinction. We find in the *Revue Industrielle* an excellent editorial summary of the Report of M. Tresca, the distinguished engineer and metallurgist, upon the machinery of the exhibition; and believing that it will prove of interest to our readers, we give the following translation of it.]

M. Tresca states at the outset that the collection in the Machinery Hall was the greatest success of the Vienna Exhibition; and that moreover, it was far superior to any similar collection shown at any preceding one. He then gives his opinion as to the value of the exhibits made by the several countries, calling attention to the distinctive character of each of these subordinate exhibitions. The Austrian constructors, he thinks, vied with each other in producing the best, to the full measure of their ability. Less fully inspired, the Germans seemed to desire to dazzle by the quantity rather than by the quality of the machines they exhibited. The Americans, the French, and the English represented much better the actual state of industry in their respective countries, even in spite of the fewness of the pieces sent. The Belgians and the Swiss were very well represented, the sections devoted to these countries containing very many beautiful specimens of constructive mechanics. Except Italy and Russia, which countries made a creditable *debut* in mechanical industry, the other nations of the world exhibited nothing remarkable in mechanics. M. Tresca then enters upon a more detailed examination of the motors of all kinds, the pumps, the machine tools, and the machines in general. "The principal driving power of modern industry," he says, "the steam engine, was, of course, represented at Vienna under the most varied forms. But even in this great variety there could be discerned without difficulty a manifest tendency, more pronounced too than in 1867, to the employment, by preference, of a lifting valve for distributing the steam, in place of the slide valve to which we are accustomed in France. This tendency should be a means of instruction to us since it is entirely justified by the facts.

"France would have been the only country not represented in this advance, had it not been for the services of M. Farcot in connection with the machine exhibited in the Belgian section by M. Bede.

"There is no need of hesitation in asserting that in this direction we are behind the times. This arises, without doubt, from the fact that we have had, up to within a very few years, the most perfect and the most economical engines. Hence, our machine constructors have counted too much on the superiority of the old, and have ignored too much the real progress which has been made. This progress was inaugurated by the improvements made in the American Corliss engine, which has been the point of departure for all the more recent advances."

"While agreeing in general," says M. Fontaine, "with this opinion of M. Tresca, as to the great merit of engines of the Corliss kind, we yet believe that it would be a grave error to assume that they are capable of replacing all other sorts of engine. Their complication and the abruptness of their movements are serious inconveniences, especially in motors of small size. Moreover, the economy of steam secured by them is not as considerable as certain constructors of these engines would have us believe. I quote again here an opinion which I have given upon this subject in another place: For a power less than twenty horse, the ordinary expansion engines are excellent; from twenty to fifty horse-powers, we should prefer, according to the purpose to be subserved, either an eccentric engine or one working with a spring-catch; above fifty horse-powers, apart from special conditions which might modify this conclusion, we should give the preference to the Corliss system of cut-off, combined with the Woolf system. On the other hand, we believe that the French engine-builders are much less behind the times in the matter of such improvements, than M. Tresca supposes. M. Legavriau, to cite only a single example, has for some years manufactured Corliss engines; and if he did not exhibit them at Vienna, it was undoubtedly only because he was too busy filling orders for them, immediately after the war."

"We are, on the contrary," continues M. Fontaine, "entirely in accord with M. Tresca, when he says in speaking of steam boilers:—

"'If any one were to form his opinion of the present state of the art of constructing steam boilers from an attentive examination of the numerous contrivances represented at Vienna, this opinion would

be strangely erroneous. While the manufacturer should seek simple combinations, such as are readily used and easily taken care of, the exhibitor is striving to complicate steam generators beyond measure, and in a thousand different ways. They even attempt to explain the reason of each peculiarity which they adopt; but their assertions are not based upon any satisfactory experimental results. It would even seem that they had sacrificed everything, blindly and without reason, to the single end—and that too, at least in fixed boilers, a secondary one—of multiplying as largely as possible the extent of the heating surface, in relation to the whole volume of the boiler.' "

The only point of progress noticed by M. Tresca in his examination of steam generators, is the employment of the Bérenger apparatus for avoiding incrustations.

In the paragraph upon locomotives, he gives a well-merited compliment to the freight engine exhibited by the Creusot Works, summarily describing the advantages of the *contrevapeur*, and calling attention to the general tendency to make the fire-boxes, and especially the grates, very large.

M. Tresca passes rapidly in review the portable engines exhibited, as well as those which are semi-portable; and also, traction engines. In relation to the latter, he considers the only really practicable ones are those of Aveling and Porter; but he does not believe that the india-rubber tires, so much puffed during late years, have given very satisfactory results.

Among the accessories to the steam engine, the author places in the first rank the products exhibited by Schœffer & Budenburg, of Magdebourg; a firm employing nearly two thousand workmen, and manufacturing detached articles, such as manometers, injectors, regulators, cocks, etc.

Under hydraulic motors, he remarks that the observed progress seems to have been rather in the direction of broader applications than in that of a more careful study of the theory of turbines. The hydraulic works at Schaffhausen and Belgarde are really on a magnificent scale.

Coming now to the examination of machines for raising water, the exhibits of MM. Bon & Lustrement, Tangy Bros., Edoux & Megy, and Etcheveria & Bazan, are cited with commendation; among pumps, the noticeable machine of M. Prunier is given as a model worthy of being copied; the direct-acting steam pumps are criticised

because of their feeble effectiveness, the rotary pumps of MM. Dumont and Edoux are specially mentioned; and the fire engines are referred to as containing the elements of a complex problem yet to be resolved.

M. Tresca begins his report upon injectors in this way: "Although the diploma of honor voted to M. Giffard, without any opposition and with perfect unanimity, by the jury on machines, was suppressed by an ulterior vote, which we may be permitted to regret; yet it is impossible, notwithstanding, not to consider the invention of this injector as one of the most remarkable and the most highly valued of French inventions; an invention to which, since then, a large number of very important improvements have been made."

"We have already noticed," says M. Fontaine, "the injustice done to M. Giffard, but we return to the subject willingly, in order to protest still again against the manœuvres employed before the Council of Presidents in order to prevent the giving to our countryman of the just reward of his beautiful invention."

The Report goes on to consider next the machine tools which were exhibited, including those for working metals, wood, and stone. In the first section, M. Tresca mentions with high commendation, MM. Sellers, Heilmann, Ducommun & Steinlen, Sharp, Stewart, Deny, Arbel, Haswell, and Brunon Bros. In the second section, he speaks especially of the machines exhibited by MM. Perin and Arbey; and in the third, he mentions those of MM. Holmes & Taylor, Dubois & Francois, Mangé & Lippmann, and Tilghman.

"We would like to be able to quote here all that part of the Report which relates to machines designed for working metals. Unfortunately, space for this fails us, and we must be contented with reproducing here three passages concerning exhibits which received the diploma of honor:

"The number of the designs—as thoroughly conceived as they were ably executed—which constituted the important exhibit of M. Sellers, constituted the most beautiful series of the entire Exhibition. M. Sellers has, however made no modifications in the arrangements of his lathe with variable velocities, by means of friction plates, which had attracted attention in 1867; nor has he changed the mode of action of the principal parts of his automatic machine for cutting gears, which is certainly the most complete machine of its kind in

use. But, nevertheless, his exhibit presents in a high degree the character of general perfection which has placed him, since 1867, in the front rank among the constructors of machine tools.

"The beautiful machine tools of MM. Heilmann, Ducommun & Steinlen (formerly Dubied & Ducommun), are as well appreciated in foreign countries as in France. It is well-known that no care is spared in their construction, and that more efficient lathes and more powerful planing machines are nowhere to be found. A single regret mingles with the unanimous decision which gave them deserved justice; and that is that this decision is to be counted among the number of successes of our neighbors, while in fact the industry developed by MM. Heilmann and Steinlen is wholly French by its origin, its progress, and its development, as well as by the talent and the energy of its directors. Without giving up a single one of the rare qualities which distinguish the fine tools which issue from this establishment, and continuing still to cement all those parts of their machines which are liable to become deformed by strain, MM. Heilmann and Steinlen, the actual directors, constructed for the exhibition a series of typical stages of the different kinds of machines. Each of these series, continued even up to the most powerful tools, is in perfect accordance with the widely varied demands of modern industry, and forms an assortment excellently well adapted to the various needs of the workshop. M. Steinlen has also rendered a signal service in the construction of machines by his study of the metric types of the dimensions of the screw threads of Whitworth, thus expressing their values in sub-divisions of the meter, and improving at the same time, by a better selection of the ratios, screws of small dimensions.

"Another industry, also entirely French, is that of M. Deny, which has for its principal specialty, the construction of all tools required in the manufacture of the thousand small metallic articles which are made in Paris by artisans at their own homes. By the side of the stamp employed in the manufacture of the links of watch chains made of brass, and of all shapes, there was exhibited some specimens of these products, which had a great success at the Exhibition. The manufacture of stamped thimbles of copper for uniting tubes together, the friction press worked by steam, the machine for the manufacture of cartridges, did not have the same importance before the jury, that was given to his method of constructing filter-presses for paper or for beet-root pulp. This is effected by means of stamped plates with beveled

channels, forming on the opposite face straight grooves having exactly the same size within a few tenths of a millimeter. These plates rolled into the form of a cylinder, always preserve the same exactness in the size of the orifices, and in this way constitute strainers excellently well suited for conducting continuous operations. The construction of these plates by M. Deny has rendered it practicable to employ various systems of continuous filter-presses, which are so important in increasing the rapidity with which, in our manufactories of indigenous sugar, the beet-juice can be extracted."

M. Tresca concludes his report with a review of the machines required in the textile arts, in various special manufactories, in printing, working leather, and in making belts; of sewing machines, of kneading machines, of grist-mills, of the apparatus employed in chemical and sugar industries, in distilling, in the manufacture of aerated waters, in breweries, and in the manufacture of candles; and of the apparatus which is used in the development of physical phenomena.

Under the head of sugar industry, there is a very favorable notice of the apparatus of Fives Lille, and a mention of the *essoreuses* with adherent motors of M. Buffaud. Under distilling, there is a compliment paid to the Savalle apparatus; and under the manufacture of aerated waters, there is much said in praise of the inventions of M. Hermann Lachapelle.

M. Tresca closes his report thus: "We see by this rapid review of the principal classes of machines exhibited, that there has not been very great progress in the mechanic arts since the Exposition Universelle of 1867. Their domain, however, has been enlarged, and the methods of construction have attained to a higher perfection. The more general utilization of the forces of nature and their application to the grand civil engineering enterprises of the day, is, among all the new advances, the one which at Vienna, presented the greatest development.

"We cannot forget that France has always remained in the front rank of mechanical industry, side by side with England, the United States, Belgium and Switzerland."

"We can add here but a word. No one has done more than M. Tresca himself, to sustain the rights of our manufacturers and to make known and recognize the supremacy of France in a host of industries. It is to his thorough knowledge of machinery that he owes the influence which enabled him to become so effective a member of the international jury.

Chemistry, Physics, Technology, Etc.

ACCOUNT OF SOME EXPERIMENTS MADE FOR THE PURPOSE OF COMPARING THE INDICATIONS OF TWO CASSELLA'S AIR METERS.

By C. B. Richards, M.E.

In some branches of physical research, and in all investigations which relate to the warming and ventilation of buildings, mines, etc., it is necessary to determine the quantity of air which flows through apertures and channels of various kinds; and, in order that incorrect conclusions may be avoided in such cases, it is important to know how great dependence can be placed on the instruments used for making these determinations. It is, therefore, believed that the following account of a series of tests of a kind of anemometer which is extensively employed, will be of value to those who may contemplate using these or similar instruments, by calling attention to some of the difficulties which attend their use.

During the last two winters, the writer of this article was engaged in conducting an extensive series of experiments for the purpose of determining the relative efficiency of various steam heaters for warming air, which will be made the subject of reports to the Smithsonian Institution and the Commission for the new Connecticut State Capitol, under whose auspices they were made. In these experiments a "Cassella's Air Meter" was employed as one of the means of measuring the quantity of air which passed through the heaters.

The results obtained from the indications of this meter were unsatisfactory and inconsistent, and, after the heating experiments were concluded, it was decided to compare the indications of two of the meters placed under conditions as nearly similar as practicable, in order to ascertain whether the results obtained from them would coincide. Arrangements were accordingly perfected for these new experiments, and the meters were tested together. Under these circumstances, *the results failed to agree*, and the experiments appear to have demonstrated that the meter indications depend to so great an

APPARATUS IN WHICH THE METERS WERE TESTED.

FIG. 1.

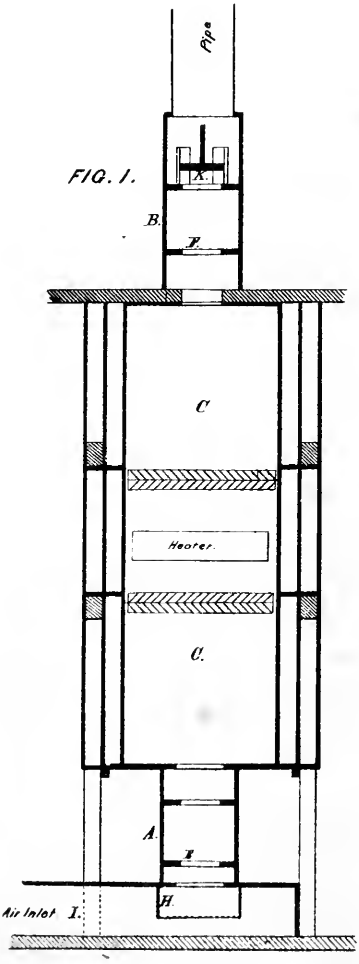
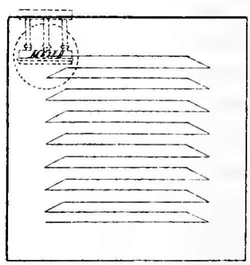
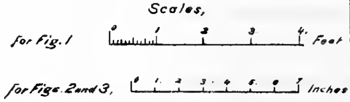


FIG. 2.

FIG. 3.



Scales,



extent on the temperature of the air and on imperceptible variations in the conditions under which the meters are placed, the effects of which cannot be predicted, but which are important, that the results are liable to lead to conclusions which may be far from correct, at least when the meters are used in comparatively small apertures.

The meter tests will be fully described in order that the correctness of this opinion may be verified or criticised.

The Cassella Meter was described in an illustrated article in the Journal of the Franklin Institute, vol. xci, page 326. The two meters employed in the tests were numbered 136 and 327. The former was kindly loaned for the purpose by President Morton of the Stevens' Institute of Technology, while meter 327 was imported by the writer directly from Cassella, in 1873, and resembled the first in every essential detail.

The meter trials were made in the apparatus which was used in testing the heaters, one meter being located and kept running in the place where a meter was used during the heating experiments, while the other was in operation in a different part of the apparatus, where it was subjected to the same conditions, as nearly as possible.

In the accompanying plate, Figure 1 is a vertical section of all the principal parts of the apparatus.

C is a large chamber with air tight walls, about 9 feet high, in the centre of which the steam heaters were placed when tested. Beneath this chamber, and opening into it, is a box *A*, provided with a glass front and a horizontal diaphragm which has through it an aperture *E* exactly 10 inches square. A similar box *B* is situated above the chamber *C*, and this box also has a glass front and a diaphragm with an aperture *F* of exactly the same size and shape as *E*. Other diaphragms having square apertures from 10 inches to 12 inches diameter are arranged above and below the apertures *E* and *F* and serve to direct the air through these.

Beneath the box *A*, and in communication with it, is a chamber *H*, the bottom of which is formed of perforated tin, which acts as a diffuser to the entering air to prevent irregular currents through *E*. The chamber *H* is immersed in a channel *I*, into which air was driven by a fan-blower during the experiments. A valve *K* in the upper part of the box *B*, served to regulate the quantity of air which passed through the whole apparatus.

One meter was placed in each of the two apertures *E* and *F*, being suspended from above so that the wind-wheel of the meter entered the aperture in the manner shown in Figures 2 and 3, in which the parts shown are drawn to a larger scale than in Figure 1.

Both meters were attached to mechanism by which they were caused to travel back and forth, with slow uniform movements, over the whole area of their apertures, in zigzag paths which are indicated in Figure 3 by a fine line. The time occupied by a meter in going over the entire area of the aperture was 3 minutes. The machinery for producing these movements need not now be described; its parts were so arranged as not to interfere essentially with the currents of air, and were exactly alike in both boxes. It is believed that, by the use of this device, the meters were presented to the different parts of the apertures in such a manner that the average velocity of currents of air through the apertures ought to have been correctly recorded by the meter if it could have been done under any circumstances.

Several thermometers, for which tables of corrections had been obtained by experiment, were hung in the boxes *A* and *B*, and an aneroid barometer and Edson's hygrodeik were placed in the lower box. All the instruments could be read by looking through the glass fronts, without opening the boxes. The following method was employed in the experiments:

The fan-blower, already referred to, was kept in motion, and air, which was taken from a room whose temperature could be regulated, was blown into the channel *I*. The direction of the air after passing the perforated bottom of the chamber *H* was upward through both the boxes and all the square apertures.

At first meter 327 was placed in the upper box *B* in the aperture *F*, and meter 136 in the lower box in the aperture *E*. Warm air was then caused to pass through the apparatus at as nearly a uniform velocity as possible, for 15 minutes, and the readings of both meters, of the barometer, the thermometers, and the hygrodeik were observed. Several experiments with various velocities of the air were tried while the meters remained in these positions, after which the meters were exchanged as to place, 327 being moved to the lower box and 136 to the upper box. A series of trials was then made, under these changed conditions, with warm air at various velocities, after which a succession of trials, each also lasting fifteen minutes, was

made with cold air at various velocities, and with the meters exchanged back and forth from one box to the other.

Repetitions of the various tests were made, and all the results have been arranged in the accompanying tables I and II. The meters were in all cases kept continually traveling over the areas of the apertures in the manner described.

The temperatures of the boxes A and B differed somewhat, owing to the passage of air over the surfaces of a heavy cast-iron "radiator" which, in the meter experiments, remained in the chamber C, but was not supplied with steam. As this mass of iron was colder than the warm air used, and warmer than the cold air, the air was either cooled or warmed a few degrees in passing from one meter to the other.

In tables I and II, the experiments are numbered in the succession in which they were made. Column 10 gives the ratios between the absolute temperatures T' and T of the air at meters 327 and 136 respectively. The velocities of the air through the 10 inch square apertures, given in columns 8 and 9, are from the observed meter readings, corrected in accordance with the tables, which the manufacturer furnishes with each instrument.

In column 11 are the ratios between the quantities of air, by weight which, according to the meters, passed through the apertures in a given time; the quantities W' and W being calculated from the corrected velocities, the temperatures of the air at the two meters being, of course, taken into account. The formula by which these last ratios were calculated is

$$\frac{W'}{W} = \frac{V'}{V} \frac{T}{T'}$$

The values of the letters and ratios are found in the columns of the tables.

Although the volume of the air was changed slightly between the two meters, by the change in its temperature which occurred in the chamber C, yet the same quantity of air, by weight, passed both meters at the same instant, for as the walls of the apparatus are air-tight, no air was added to or taken from the quantity which entered the chamber H, in its course through the apparatus. If, therefore, the indications of the two meters, when modified by the proper corrections, had coin-

cided, the ratios $\frac{W'}{W}$ in column 11 would have been unity in all cases, and the deviations from unity which the numbers in this column show, indicate directly the discrepancies between the two meter results. These discrepancies are more plainly shown in columns 12 and 13, from which we learn that, according to the corrected readings, when meter 327 was in the upper aperture, it indicated, at low velocities, *with warm air*, 29 *per cent. more* than 136 did in the lower aperture; while *with cold air*, it indicated 30 *per cent. less.* But, when their relative positions were exchanged, and 327 was placed in the lower aperture, it indicated *with warm air*, 30 *per cent. less* than 136 did in the upper aperture, but *with cold air*, 27 *per cent. more.*

The conditions in which the meters were placed were, as nearly as could be ascertained, alike in both apertures, except in respect to temperature; and all the conditions were certainly as carefully observed in these experiments as they would be in most experimental uses of this kind of instrument. The results of these experiments then seem to show that the indications of the two meters differed so widely, and in such a manner, as to destroy confidence in their usefulness when they are employed under circumstances at all similar to those described.

The variations in the meter indications do not seem to follow any easily recognized law.

Colt's Armory, Hartford, Conn., May 29th, 1875.

Intensity of Colored Lights for Illumination.—Some experiments have recently been made at Trieste with a view to testing the intensity of colored lights, and of white light with different oils. While no doubt was entertained that the best effect with lights at a distance was had with white light, and the next best with red, it was desired to ascertain the comparative utility of other colors for harbor lights. Small hand lanterns were used with white, red, green, deep, and dark blue glasses. With the white were used American petroleum, parraffin, and olive oil. At half a mile distance the dark blue was quite invisible, and the deep blue hardly visible (showing their uselessness for illumination at sea). The experiments made to a distance of two nautical miles, gave the following results: 1. That white light with petroleum is more intense than with parraffin,—the latter also went out several times, so it lacked the necessary certainty. 2. That among the lights with olive oil, the red was the brightest—after the white—and the green (Bohemian make) after the red. The green light may at short distances be made to alternate with the white.

TABLE I.—Meter 327 in the UPPER Aperture F, and Meter 136 in the Lower Aperture E.

Number of the Experiment.	Condition of the air. Barometric pressure.	Condition of the air. Moisture. Degree of Saturation.	Temperature-Fahrenheit, at Meter 327	Temperature-Fahrenheit, at Meter 136	Velocity of the air per minute. Observed from Meter 327	Observed from Meter 136	Corrected by Cassella's tables for Meter 327	Corrected by Cassella's tables for Meter 136	$\frac{T}{T'}$	$\frac{W'}{W}$	Excess 327 over 136	Excess 136 over 327
1	2	3	4	5	6	7	8	9	10	11	12	13
	Inches.	Per cent.	°	°	Feet.	Feet.	Feet.	Feet.			Per cent.	Per cent.
5	30·16	...	71	76	104	84	137	109	1·01	1·27	27	
6	30·16	...	70	74	110	87	143	112	1·01	1·29	29	
24	30·23	37	75	79	121	102	156	127	1·01	1·24	24	
4	30·16	...	71	79	135	115	170	139	1·01	1·24	24	
3	30·16	...	70	79	187	183	225	203	1·02	1·13	13	
1	30·16	...	61	74	201	211	240	230	1·02	1·07	7	
2	30·16	...	67	77	206	208	245	227	1·02	1·10	10	
25	30·23	37	78	85	218	218	257	238	1·01	1·09	9	
19	30.37	26	87	92	233	235	273	253	1·01	1·09	9	
18	30·37	26	86	91	235	232	276	250	1·01	1·12	12	
26	30·23	37	81	88	266	280	308	297	1·01	1·05	5	
17	30·37	26	85	90	275	289	317	305	1·01	1·05	5	
31	29·72	66	44	39	55	97	86	122	0·99	0·70		30
14	30·38	72	43	36	68	104	99	129	0·99	0·76		24
30	29·72	66	44	41	69	114	100	138	0·99	0·72		28
15	30·38	72	40	34	89	125	121	148	0·99	0·81		19
29	29·72	66	44	42	106	149	140	171	1·00	0·82		18
16	30·38	72	39	34	107	147	141	169	0·99	0·82		18
28	29·72	66	44	42	110	149	143	171	1·00	0·83		17
27	29·72	66	44	41	122	108	157	180	0·99	0·87		13

TABLE II.—Meter 327 in the LOWER Aperture E, and Meter 136 in the Upper Aperture F.

Number of the Experiment.	Condition of the air. Barometric pressure.	Moisture. Degree of Saturation.	Temperature Fahrenheit, at Meter 327	Meter 136	Velocity of the air per minute. Observed from Meter 327	Meter 136	Corrected by Cassella's tables for Meter 327	Meter 136	$\frac{T}{T'}$	$\frac{W'}{W}$	Excess 327 over 136	Excess 136 over 327
1	2	3	4	5	6	7	8	9	10	11	12	13
	Inches.	Per cent.	°	°	Feet.	Feet.	Feet.	Feet.			Per cent.	Per cent.
7	30·16	...	74	69	63	109	94	133	0·99	0·70		30
8	30·16	...	77	70	104	141	137	164	0·99	0·82		18
23	30·23	37	82	76	107	149	140	171	0·99	0·81		19
22	30·23	37	84	78	133	172	168	193	0·99	0·86		14
9	30·16	...	83	73	174	194	212	214	0·98	0·97		3
10	30·16	...	84	76	213	230	253	248	0·98	1·00	0	0
21	30·23	37	85	78	218	232	257	250	0·98	1·01	1	
20	30·23	...	84	76	274	269	317	286	0·98	1·09	9	
32	29·73	76	39	44	74	60	106	87	1·01	1·23	23	
13	30·38	72	34	41	88	84	120	109	1·01	1·12	12	
33	29·73	76	40	44	102	82	135	107	1·01	1·27	27	
12	30·38	72	30	39	145	132	181	156	1·01	1·19	19	
34	29·73	76	42	44	146	120	181	144	1·00	1·26	26	
11	30·38	72	30	45	176	165	213	186	1·03	1·18	18	
35	29·73	76	43	45	188	150	226	172	1·00	1·32	32	

SYMPATHETIC VIBRATION.*

By Henry A. Rowland, C. E.

I. *Experimental.*

Among the most curious mechanical facts which we observe in nature, those which we class under the head of sympathetic vibration seem to me to stand forth quite prominent, and the more we study them the more we are convinced of their wide-spread nature.

We all learn the fundamental facts with regard to this subject in our childhood when we go out to "take a swing." Here one person sits on a board so that he can vibrate back and forth in times of nearly equal duration, while another person pushes him as he goes forward, but stops pushing as he comes back. In this way the work done by the person pushing is gradually stored up in the other, and the amplitude of his vibration increases until the work done is equal to the work spent against the resistance of the air, when no further increase is obtained.

In this case we observe that to have the vibration regular and as great as possible, the pushes must be regular and made only while the swing is going forward. If the pushes are irregular the vibrations will be irregular and will never obtain great amplitude. These principles hold in all cases of sympathetic vibration, as we shall see as we proceed. To illustrate this case experimentally we can use the method which I have already described some years back: Let us make two pendulums of equal length by hanging bullets to fine silk thread and let us hang the pendulums near each other, but so far apart that they can swing freely; and, further, let us connect the strings of the pendulums near the top by a piece of fine yet stiff wire. On now drawing aside either of these pendulums in the plane containing the two and letting it vibrate, the other soon commences to move, and its excursions to either side increase more and more until we are soon surprised to observe that its vibrations have greater amplitude than those of the first; and soon after the first pendulum comes to rest and the second has entirely absorbed its motion. But soon the first moves once

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* Read before the Pi Eta Scientific Society of the Rensselaer Polytechnic Institute, Troy, N. Y., and communicated by the author.

more, its motion increases and it is not very long before it has regained it all once more, and were it not for friction, the system would now be in exactly its initial state. And so these two pendulums keep on exchanging motion until friction has destroyed it and the vibratory motion of the pendulums becomes the motion of heat. But if one of the pendulums is a little longer than the other the motion is no longer exchanged, but the second one still moves to some extent. But it soon comes to rest once more only to commence again.

These phenomena can also be observed on a sonometer having two strings tuned in unison. On causing one to vibrate the other soon commences, and if we withdraw the bow it will absorb nearly all the motion from the first string only to give it back to it once more after an equal interval of time. If the strings are not exactly in unison the second will still respond to the first but it will not absorb *all* the motion from the first.

In the experiment of the pendulums, if we make one of the pendulum balls larger than the other and then regulate the lengths until the proper ones are reached, the motion will still be exchanged, provided there is not too great difference of size. It is interesting to observe in this case that when the small ball has the motion the amplitude of vibration is larger than when the large ball has it, and this, I consider, to be a beautiful illustration of the conservation of energy.

By taking measurement we might prove by experiment that the kinetic energy of a body is measured by the half product of the mass by the square of the velocity, a proposition which, I am sorry to say, has been recently disputed by a writer in a journal of repute. When one of the balls is made very large, the motion is no longer exchanged, owing to the resistance of the air on the small ball. This last case corresponds exactly to the case of the swing.

All these experiments can be repeated in a most excellent manner on bodies swinging by torsion. Plate I, Fig. 1 represents two balls of considerable weight, hung so that they can swing freely by torsion, in nearly equal times. Near the top of the wires are attached two light cross pieces, *c* and *d*, at right angles to the plane containing the wires, and these are joined together by the threads, *b* and *k*. When properly regulated the motion is exchanged in the most perfect manner, and as the resistance is less than in the case of pendulums, the motion is kept up longer. The wires for torsion can evidently be replaced by a bifilar suspension.

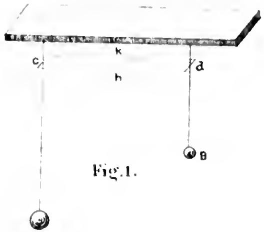

Fig.1.

Fig.2

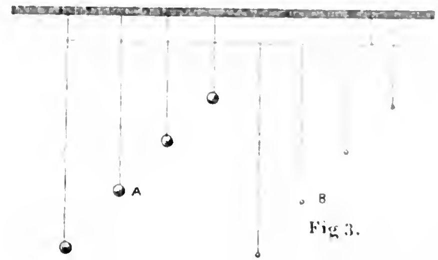

Fig.3.

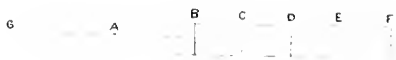

Fig.4.

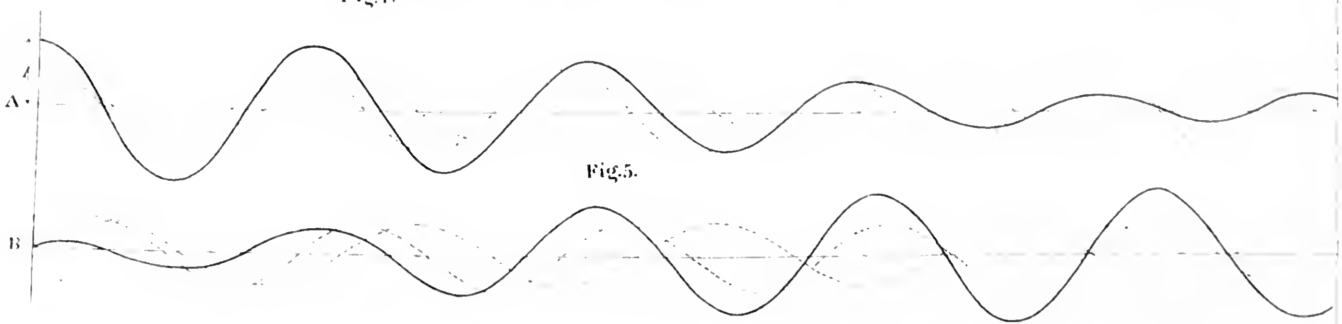

Fig.5.

We can modify the above by suspending one ball from the other, as in Plate I, Fig. 2. Here the ball A is very heavy, and is suspended by a quite thick wire, and the ball B is light and is suspended by a thin wire, so that the time of vibration of A is nearly the same as that of B. The first ball is so heavy that its vibrations are little affected by B and it becomes a nearly fixed point for the suspension of B. Hence, the two balls are in a measure independent of each other. The results with this are very curious. When properly adjusted, a vibration of A through a few degrees will soon cause the small ball to oscillate through one or more complete revolutions. The motion is exchanged in this case very completely. The suspension of A can be bifilar if desired.

If the wires in this arrangement are replaced by threads, we get still other effects; for when the lengths of the threads are properly adjusted, that is, are of nearly equal lengths, we can swing either of them as a pendulum and the other will answer to it. Thus a motion of the large ball through a small fraction of an inch may, in time, cause the small ball to vibrate through a foot or more, and the two will continue to exchange motion for some time. If one of the balls is made to describe an ellipse, the other will follow it after a time on a larger or smaller scale as the case may be.

Let us now, before proceeding further, glance over the laws which we can glean from the above experiments. We see then, in the first place, that to have bodies respond to each other to any great extent, the times of their vibrations when free from each other must be *nearly* the same. It is often stated that they must be *exactly* the same, but I shall show when we come to the mathematical discussion that the times must differ slightly. In the second place the two bodies must be connected in some way so that *each must influence the other's vibrations*. We also observe that except for friction and other losses the energy of the system is a constant quantity, so that the two bodies are never vibrating to their fullest extent at the same time, but when one has the greatest motion the other has the least. And lastly, on closely examining the vibrating bodies, for which purpose the pendulums are the best, we perceive that the body to which motion is being given always lingers behind that which is giving it motion.

As we study other cases we shall see that these laws are general and apply to all kinds of sympathetic vibration.

In all the cases which we have hitherto considered, the connection between the vibrating bodies has been of the most obvious character; in the case of pendulums it was the wire between them, and in that of the two strings it was the bridge over which those strings were strung. But other methods of connection are at hand: thus we could attach magnets to the two pendulums which by their mutual repulsion would take the place of wire. But the best way of trying this experiment is to prepare two magnets so as to vibrate in nearly equal times by loading the one which vibrates too fast until it is adjusted; if they have equal moments of inertia the times of vibration must be exactly equal. They may then be hung east and west from each other or in other positions if preferred, and they will then be found to exchange their vibratory motion in a remarkable manner.

In the well-known experiment where one tuning fork is made to respond to another of equal pitch sounded near it, the medium of communication is the air in which waves are formed. But it is not so easy to see how the vibrations of the primary fork are effected by those of the secondary one. When, however, we come to study the matter, we shall see that the secondary fork also gives out waves in such a phase that when they strike on the primary fork they diminish its vibrations. The motion is not generally exchanged in this case, because by far the greatest amount of the energy of the forks goes to producing waves in the air rather than motion in each other; but it is probable it does take place to some extent.

The science of Acoustics furnishes many other beautiful illustrations of sympathetic vibration. Thus when we bring a tuning-fork near an open vessel of proper size, containing air, we perceive a strengthening of the sound, which is called resonance. The air in the vessel in this case is the vibrating body, and could we make sufficiently delicate experiments it would appear that the vibration of the tuning-fork was affected by that of the air. This is shown in the case of the reed-pipe, with tube attached, and which is nothing but a modified case of resonance. Were the reed free its time of vibration would be fixed; but when it is in place the tone given out depends not only on the reed, but also on the pipe, thus showing that they modify each other's vibrations.

A striking case of sympathetic vibration is seen in sensitive flames, smoke-jets, and jets of water, for a description of which I refer the reader to Prof. Tyndall's excellent work *On Sound.*

Our knowledge of sympathetic vibration is of much use to us where we wish to analyze a given compound vibration and pick out its elements; for it can be demonstrated mathematically that in no matter how irregular a manner a body may vibrate, we may still suppose its motion to be made up of a number of regular vibrations, superimposed on each other. Having such a vibration, then, we are required to find its component vibrations. To produce the irregular vibration in question, we can construct the apparatus shown in Plate I, Fig. 3.* To the lower edge of a board four or five feet long we suspend a number of pendulums, varying in length from five or six inches to about twenty inches, and weighing an ounce or two each. We then select a stiff wire—steel being the best—of about No. 17 gauge, and as long as the board, and hang it beneath the edge of the board by fine threads, an inch or so long. We then tie the pendulum threads to the wire at the points where the two cross.

On now starting a number of the pendulums at the same time, the wire is drawn hither and thither by the conflicting pulls of the pendulums, and if there are many of these one can hardly detect any regularity in its motion; but it is regular, not only because it is the sum of a number of regular motions, but because we can again decompose it into its elements; for, on now hanging on the wire several light pendulums, they will be agitated by the motion, but none of them will vibrate to any extent unless its time of vibration is similar to that of one of the heavy pendulums. In this case it will pick out that vibration, which is similar to its own, and will soon attain great motion.

In the apparatus shown in Fig. 3, the pendulums *B* should be adjusted until the time of vibration of each equals that of the corresponding pendulum of *A*, after the whole apparatus is together, and while each pendulum is in place; and I may warn those who wish to construct it, that it must be done with care.

A beautiful apparatus of this same nature has been described by Prof. Mayer. Having arranged an organ pipe in its proper position, with respect to some tuning-forks, he attaches a prong of each of them to one point on the face of the organ pipe by means of a silk fibre. The air in the organ pipe has, in general, a compound vibra-

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* This was first described by me in the JOURNAL OF THE FRANKLIN INSTITUTE, Vol. xciv, p. 275, 1872.

tion due to its dividing into nodes and loops, and so gives the point on the organ pipe a motion similar to the wire in the pendulum experiment, and the elements of this motion are shown by those tuning-forks which vibrate.

As a general rule, when a note is struck upon any instrument, we obtain besides the fundamental note a number of other notes of a higher pitch mingled with it, and called over-tones or harmonics. In some cases the ear is able to detect these, but in others this is not possible. But Helmholtz has found a method, based upon sympathetic vibration, by which we can do this in all cases. For this purpose he uses what are known as resonance globes, which are merely globes of different sizes, with two openings, one for placing to the ear, and the other for the admission of the sound. Should the sound contain any component vibration to which the air in the globe can vibrate, it can be instantly perceived by the person using the globe.

Kœnig places a number of these globes on a stand together, and the vibration of the air in them is shown by the flickering of gas-jets attached to them in a certain way.

We have now come to another part of our subject of a somewhat different nature from that we have been considering. Hitherto the bodies we have used have been, for the most part, capable of vibrating in only one given time; but, as a general rule, most bodies are capable of vibrating in a number of ways. Thus a stretched string can either vibrate as a whole, or can divide up into a number of different parts, each of which vibrates; and so from a given string we can obtain a large number of notes.

Such a body as we have described is capable of sympathetic vibration as well as one of the other kind, and will, if possible, accommodate itself to the vibrating body.

Thus two strings of a sonometer, when tuned to unison, will respond to each other, not only when sounding the fundamental note, but also when the first string is divided in any way; and it is easily shown by placing paper riders upon the wires that they are both divided in the same manner.

This is also the case with the vibration of plates, as may be shown by sprinkling sand on them to bring out the nodal lines. When two equal plates are placed above each other, with only a few inches of air between the two, and the upper plate is caused to sound by a

violin bow so as to produce a certain configuration of nodal lines on that plate, we shall perceive, on taking away that plate, that the sand on the plate below is arranged in exactly the same series of nodal lines.

Melde's experiment, of causing a string to vibrate by attaching it to one of the prongs of a tuning-fork, is also a case in point.

When small vessels of different shapes, containing mercury, are placed on the cases of musical instruments capable of giving out a continuous sound, the surface will divide up in a series of stationary waves, intersecting the surface in the most beautiful manner. This effect varies with the shape of the vessel and note sounded.*

Some of the principles of sympathetic vibration can be applied to the giving to and receiving of vibrations from air. Free air can vibrate in an infinite number of ways, and we may not at first see how it comes under the head of sympathetic vibration. However, the connection between the two will be apparent by simple reasoning.

In Fig. 4, let $G\,B$ be a brass rod, firmly fixed at A, and with a light piston, B, at one end loosely fitting the glass tube, $B\,F$. On now causing the rod to vibrate longitudinally by means of a piece of cloth containing resin, and having sprinkled some light powder in the tube, if we place a piston at some point, C, the air in the tube at $B\,C$ will vibrate in response to the rod, as shown by the motion of the dust. This is a case of sympathetic vibration of the first kind. By placing the piston at F the air will divide into nodes as in sympathetic vibration of the second kind. Now, if we remove the piston, and afterward the tube, it is evident that though we shall have no nodes and loops in this case, yet there is a similarity in the two cases. For the stationary waves may be considered as formed by the repeated reflection of progressive waves from the two ends of the tube.

Let us now descend from bodies of finite size to the molecules of a body and see whether they have any actions which we can explain by sympathetic vibrations. No man can say what is the shape or size of a molecule, or in what way it moves, but of this we are almost certain that either the molecules themselves, or some parts of them, have a periodic motion of some kind which we may suppose to be a

* For some excellent drawings of these see Ann. de Chim. et de Phys., 5me Serie, Tome i, p. 100

vibration. For when a gas is heated the waves of light which it gives out have a definite period of vibration, as is shown by the spectroscope. Hence, we should suppose that when those same waves strike upon another portion of the gas the particles of that gas would be set in motion by the waves. But to give the molecules motion, the motion of the waves must cease as we have seen it to do in the case of the two pendulums which exchange motion. Hence, we arrive at the law that those rays which a body gives out when heated will be absorbed by that body when they strike upon it. This, then, is the complete explanation of the dark lines in the solar spectrum; and we also deduce from this the theory of exchanges as it is called which has been developed in a most beautiful manner by Prof. Balfour Stewart.

We cannot suppose that the motion of the waves is accumulated in the molecules without limit; there must be something to take away their motion as it is given to them by the waves. We do not know what this is, but it may be that the molecules give out their motion once more in waves radiated in all directions, so that certain of the waves which compose the white light may be dispersed in all directions when passing through the gas, and thus the *direct* beam of light will lose most of those rays.

II. *Mathematical.*

The theory of this subject is simple, and at the same time very interesting, and, as I have not seen it treated elsewhere, I will spend a few moments in giving it.

$$\underset{\cdot}{D} \quad \underset{\cdot}{A} \qquad \underset{\cdot}{C} \quad \underset{\cdot}{B}$$

Let the two bodies A and B be drawn to the points D and C, respectively, by forces which vary directly as the distances from those two points. And also let the two bodies be so connected, as, for instance, by a spring, that the mutual force between them will be proportional to the compression or stretching of the spring.

The two bodies, were they free from each other, would be capable of vibrating about the points D and C without influencing each other but as they are connected the case will be different.

Let n and n' be the masses of the two bodies.

Let x and y be the distances DA and CB respectively.

Let g and g' be the forces acting on the bodies when x and y are unity.

Let h be the force required to compress the spring by unity of length.

Then the equations to the motions of the two bodies are

$$\frac{d^2x}{dt^2} = -\frac{g}{n}x + \frac{h}{n}(y-x) \text{ and } \frac{d^2y}{dt^2} = -\frac{g'}{n'}y - \frac{h}{n'}(y-x),$$

$$\text{or, } \frac{d^2x}{dt^2} = -x\frac{h+g}{n} + y\frac{h}{n} \text{ and } \frac{d^2y}{dt^2} = x\frac{h}{n'} - y\frac{h+g'}{n'}$$

$$\text{Let } a = -\frac{h+g}{n}; \quad b = \frac{h}{n}; \quad a' = \frac{h}{n'}; \quad b' = -\frac{h+g'}{n'}.$$

The solution of these equations can be obtained by the method used by Boole (see Differential Equations, p. 310), and we shall then find:

$$x + m_1 y = C_1 e^{t\sqrt{a + a'm_1}} + C_2 e^{-t\sqrt{a + a'm_1}}$$

$$x + m_2 y = C_3 e^{t\sqrt{a + a'm_2}} + C_4 e^{-t\sqrt{a + a'm_2}}$$

where m_1 and m_2 are the two roots of the equation,

$$am + a'm^2 = b + b'm.$$

To determine the constants let the bodies at the time $t = 0$ be at rest, and so

$$\frac{dx}{dt} = 0 \text{ and } \frac{dy}{dt} = 0 \therefore C_1 = C_2 \text{ and } C_3 = C_4;$$

also when $t = 0$ let the body B be at C, and the body A be in the position $x = l$. Hence

$$C_1 = C_2 = \frac{l}{2} \text{ and } C_3 = C_4 = \frac{l}{2};$$

But from a well known theorem,

$$e^{pq\sqrt{-1}} + e^{-pq\sqrt{-1}} = 2\cos pq.$$

Hence we have finally,

$$(1) \quad y = \frac{l}{m_1 - m_2}\left\{\cos(t\sqrt{-a - a'm_1}) - \cos(t\sqrt{-a - a'm_2})\right\}$$

(2) $$x = \frac{m_{,}m_2 l}{m_2 - m_{,}} \left\{ \frac{1}{m_{,}} \cos\left(t\sqrt{-a-a'm_{,}}\right) - \frac{1}{m_2} \cos\left(t\sqrt{-a-a'm_2}\right) \right\}$$

in which

$$m_1 = \frac{1}{2hn} \left\{ (h+g')\,n - (h+g)\,n' + \sqrt{\{(h+g)\,n' - (h+g')\,n\}^2 + 4h^2nn'} \right\} \quad m_2 = \frac{1}{2hn} \left\{ (h+g')\,n - (h+g)\,n' - \sqrt{\{(h+g)\,n' - (h+g')\,n\}^2 + 4h^2nn'} \right\}$$

When $h = 0$ there is no connection between the bodies, and the equations become

(3) $$y = 0 \text{ and } x = l \cos\left(t\sqrt{\frac{g}{n}}\right)$$

from which we see that B remains at rest and A oscillates indefinitely in the time $\pi\sqrt{\frac{n}{g}}$, the case of an ordinary pendulum. When, however, the bodies are attached together so that h has a value greater than zero, the case is different. In most cases of sympathetic vibration the bodies only influence each other slightly, so that the value of h is small; hence in the discussion we shall assume that h is small.

Equation (2) gives us the position of the first body at any instant t; and equation (1) gives us that of the second body.

In both cases the values of x and y depend upon two periodic terms, so that the motion of each body is a vibration compounded of two simple or harmonic vibrations; and, indeed, the motion of each may be represented by the same figure used to illustrate beats in the theory of sound.

Thus in Fig. 12 the horizontal lines represent the time t, the dotted curves the values of two terms in the equations, and the ordinates of the full curves the values of x and y. The figure represents the general case when the entire motion is not exchanged. We here observe that as t increases the motion of A is gradually given to B, so that the oscillations of A continually decrease in amplitude, while those of B increase until we get to a certain point, where the reverse takes place. In this case the first body never entirely comes to rest.

To see in what manner the bodies must be arranged in order that the motion of the second pendulum shall be the greatest possible, we proceed as follows:

The largest value which y can have as t increases is when

$$\cos\left(t\sqrt{-a-a'm_{\prime}}\right)=1 \text{ and } \cos\left(t\sqrt{-a-a'm_2}\right)=-1,$$

and, therefore, $y_1=\dfrac{2l}{m_2-m_{\prime}}$ is the largest value of y.

This is a maximum when

$$(h+g)n'-(h+g')n=o'$$

$$\text{or, } \frac{g'}{n'}=\frac{g}{n}+h\frac{n'-n}{nn'}$$

When the bodies are only slightly connected, so that h is small, we have $\dfrac{g'}{n'}=\dfrac{g}{n}$ which, in eq. (3), shows that the time of vibration of the two bodies must be the same.

But, in general, $\dfrac{g'}{n'}$ will have a greater or less value than this, according as n' or n is the greater; so that the time of vibration of the heavier body must be less, when vibrating freely, than the other body.

When this adjustment is made the maximum value of y is $l\sqrt{\dfrac{n}{n'}}$ and at the same time x becomes o. The original amplitude of vibra- of the body A was $2l$, and after they had exchanged motions B has the amplitude $2l\sqrt{\dfrac{n}{n'}}$ so that the maximum amplitudes of two bodies exchanging motion in this way are inversely as the square roots of their masses.

In this case, when the bodies are adjusted for the best effect, we have

$$4\left\{\begin{aligned} y&=\tfrac{1}{2}l\sqrt{\frac{n}{n'}}\left[\cos\left\{t\sqrt{\frac{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}{n}}\right\}-\cos\left\{t\sqrt{\frac{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}{n}}\right\}\right]\\ y&=\tfrac{1}{2}l\left[\cos\left\{t\sqrt{\frac{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}{n}}\right\}+\cos\left\{t\sqrt{\frac{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}{n}}\right\}\right]\end{aligned}\right.$$

These equations show that as t increases the vibrations of A become less and less, and those of B greater and greater, until a certain time, after which the reverse takes place and A regains its motion.

To find the time of this cycle we can proceed as follows: The two terms in the equations are periodic, and return to their primitive value after the times

$$2\pi\sqrt{\left\{\frac{n}{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}\right\}} \text{ and } 2\pi\sqrt{\left\{\frac{n}{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}\right\}}$$

Now, whenever they both arrive at their initial state together, the whole system will be in its initial state, and this will happen whenever s times the first is equal to p times the second, s and p being any positive whole numbers determined by the equation.

$$\frac{s^2}{p^2}=\left\{\frac{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}\right\}$$

This cannot always be exactly satisfied for small values of s and p unless there is a certain relation between the quantities in the right-hand member; but by giving large enough values it can always be satisfied. The time of the cycle will then be

$$2\pi s\sqrt{\left\{\frac{n}{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}\right\}}$$

It is to be noted that several apparent exchanges of motion may take place before the complete cycle in which the system returns exactly to its initial state is gone through with.

If in eqs. (4) we make n very great and b very small the amplitude of A will remain almost undiminished and that of B will increase indefinitely. This is the case of a large, heavy body giving motion to a light one, which is only slightly connected with it.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA. NO. 1.—A NEW VERTICAL-LANTERN GALVANOMETER.*

By George F. Barker, M.D., Professor of Physics.

Desiring to show to a large audience some delicate experiments in magneto-electric induction, in a recent lecture upon the Gramme machine, a new form of demonstration galvanometer was devised for the purpose, which has answered the object so well that it seems desirable to make some permanent record of its construction.

Various plans have already been proposed for making visible to an audience the oscillations of a galvanometer needle; but they all seem to have certain inherent objections which have prevented them from coming into general use. Perhaps the most common of these devices is that first used by Gauss in 1827, and adopted subsequently by Poggendorff and by Weber, which consists in attaching a mirror to the needle. By this means, a beam of light may be reflected to the zero point of a distant scale, and any deflection of the needle made clearly evident. The advantages of this method are:—1st, the motion of the needle may be indefinitely magnified by increasing the distance of the scale, and this without impairing the delicacy of the instrument; and 2d, the angular deflection of the needle is doubled by the reflection. These unquestioned advantages have led to the adoption of this method of reading in the most excellent galvanometers of Sir William Thomson. While therefore, for purposes of research, this method seems to leave very little to be desired, yet for purposes of lecture demonstration it has never come into very great favor; perhaps because the adjustments are somewhat tedious to make, and because, when made, the motion to the right or left of a spot of light upon a screen fails of its full significance to an average audience.

Another plan is that used by Mr. Tyndall in the lectures which he gave in this country. In principle, it is identical with that employed in the megascope; *i. e.*, a graduated circle over which the needle moves is strongly illuminated with the electric light, and then by means of a lens a magnified image of both circle and needle is formed

*A paper read before the Franklin Institute, June 16, 1875.

on the screen. The insufficient illumination given in this way, and the somewhat awkward arrangement of the apparatus required, have prevented its general adoption.

A much more satisfactory arrangement was described by Professor Mayer in 1872,* in which he appears to have made use, for the first time, of the excellent so-called vertical lantern in galvanometry. Upon the horizontal plane face of the condensing lens of this vertical lantern, Mayer places a delicately balanced magnetic needle, and on each side of the lens, separated by a distance equal to its diameter, is a flat spiral of square copper wire, the axis of these spirals passing through the point of suspension of the needle. A graduated circle is drawn or photographed on the glass beneath the needle, and the image of this, together with that of the needle itself, is projected on the screen, enlarged to any desirable extent. The defect of this apparatus, so excellent in many respects, seems to have been its want of delicacy; for in the same paper the use of a flat narrow coil, wound lengthwise about the needle, is recommended as better for thermal currents. Moreover, a year later, in 1873,† Mayer described another galvanometer improvement, entirely different in its character. In this latter instrument, the ordinary astatic galvanometer of Melloni was made use of, an inverted scale being drawn on the inside of the shade, in front of which traversed an index in the form of a small acute rhomb, attached to a balanced arm transverse to the axis of suspension of the needle, and moving with it. The scale and index were placed in front of the condensing lenses of an ordinary lantern, and their images were projected on the screen in the usual way by use of the objective. This instrument is essentially the same in principle as the mirror galvanometer; but it cannot be as sensitive as the latter, while it is open to the same objection which we have brought against this —the objection of unintelligibility. In the hands of so skillful an experimenter as Mayer, it seems, however, to have worked admirably.

It was a tacit conviction that none of the forms of apparatus now described would satisfactorily answer all the requirements of the lecture above referred to, that led to the devising of the galvanometer now to be described, which was constructed in February of the

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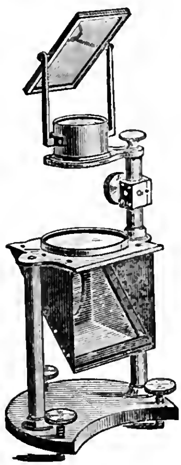
*Journal Franklin Institute, III. lxiii. 421, June, 1872. American Journal of Science, III. iii. 414, June 1872.

†American Journal of Science, III, v, 270, April, 1873.

present year. Like the first galvanometer of Mayer, the vertical lantern, as improved by Morton,* forms the basis of the apparatus. This vertical lantern, as constructed by George Wale & Co., at the Stevens Institute of Technology, as an attachment to the ordinary lantern, is shown in the annexed cut, Figure 1. Parallel rays of light, from the lantern in front of which it is placed, are received upon the mirror, which is inclined 45° to the horizon, and are thrown directly upward, upon the horizontal plano-convex lens just above. These rays, converged by the lens, enter the object glass, and are thrown on the screen by the smaller inclined mirror placed above it. The upper face of the lens forms thus a horizontal table, upon which water-tanks, etc., may be placed, and many beautiful experiments shown. To adapt this vertical lantern to the purposes of a galvanometer, a graduated circle, photographed on glass, is placed upon the horizontal condensing lens. Above this, a magnetic needle, of the shape of a very acute rhomb, is suspended by a filament of silk, which passes up through a loop, formed in a wire stretched close beneath the object glass, and thence down to the side pillar which supports this objective, where it is fastened by a bit of wax, to facilitate adjustment. The needle itself is fixed to an aluminum wire, which passes down through openings drilled in the scale glass, the horizontal lens, and the inclined mirror, and which carries a second needle near its lower end.† Surrounding this

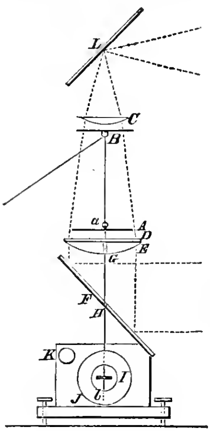


(Fig. 1.)

*Jour. Frank. Inst., III, lxi, 300, May, 1871; Am. J. Sci., III, ii, 71, 153, July, Aug., 1871; Quar. J. Sci., Oct., 1871. In Duboscq's vertical attachment, which was advertised in his catalogue in 1870, the arrangement is similar, except that the beam received upon the mirror is a diverging one, and consequently the horizontal lens is of shorter focus. A total reflection prism, placed above the object glass, throws the light to the screen. The instrument gives a uniformly illuminated but not very bright field.

†After the new galvanometer was completed and had been in use for several weeks, I observed, in re-reading Mayer's first paper, a note stating that the idea had occurred to him of using an astatic combination consisting of two needles, one above the lens and the other below the inclined mirror—the two being connected by a stiff wire passing through holes in the condenser and the mirror. The plan of placing the coil round the lower needle does not seem to have suggested itself to him. Indeed, it does not appear that the arrangement he mentions was ever carried into practical effect.

lower needle is a circular coil of wire, having a cylindrical hollow core of an inch in diameter, in which the needle swings, and a smaller opening transverse to this, through which the suspension wire passes. In the apparatus already constructed (in which the upper needle is five centimeters long), the coil is composed of 100 feet of No. 14 copper wire, and has a resistance of 0·235 ohm. The accompanying cross section (Fig. 2,) of the vertical lantern galvanometer as at present arranged, drawn on a scale of 1-12, will serve to make the above description more clear. A is the needle, suspended directly above the scale-glass D, by a silk filament, passing through the loop B, close under the objective C. This needle is attached to the aluminum wire *a b*, which passes directly through the scale-glass D, the condensing lens E, and the inclined mirror F at H, and carries, near its lower end, the second needle I. This needle is shorter, (its length is 2·2 centimeters,) and heavier than the upper one, and moves in the core of the circular coil J, whose ends connect with the screw-cups at K. This coil rests on the base of the lantern, enclosed in a suitable frame. It is obvious that when the instrument is so placed that the coil is in the plane of the meridian, any current passing through this coil will act on the lower needle, and, since both needles are attached to the same wire, both will be simultaneously and equally deflected. Upon the screen is seen only the graduated circle and the upper needle; all the other parts of the apparatus are either out of the field or out of focus. Moreover, the hole in the lens is covered by the middle portion of the needle, and hence is not visible. The size of the image is, of course, determined by the distance of the galvanometer from the screen; in class experiments, a circle 8 feet in diameter is sufficient; though in the lecture above referred to, the circle was 16 feet across, and the needle was fourteen feet long, the field being brilliant.



(Fig. 2.)

The method of construction which has now been described, is evidently capable of producing a galvanometer for demonstration, whose delicacy may be determined at will, depending only on the kind of work to be done with it. In the first place, the needles may be made more or less perfectly astatic, and so freed more or less completely from the action of the earth's magnetism, and consequently more or less sensitive. Moreover, an astatic system seems to be preferable

to one in which damping magnets are used, since it is freer from influence by local causes; though, if desirable for a coarser class of experiments, the considerable distance which separates the needles in this instrument, allows the use of a damping magnet with either of them. In the galvanometer now in use, the upper needle is the stronger, and gives sufficient directive tendency to the system to bring the deflected needle back to zero quite promptly. In the experiments referred to below, the system made 25 oscillations per minute.

Secondly, the space beneath the mirror is sufficiently large to permit the use of a coil of any needed size. Since, therefore, the lower needle is entirely enclosed within the coil, the field of force within which it moves, may be made sensibly equal at all angles of deflection, as in the galvanometers of Sir Wm. Thomson. Hence the indications of the instrument may be made quantitative, at least within certain limits. The circular coil, too, has decided advantages over the flat coil, since the mass of wire being nearer to the needle, produces a more intense field. Were it desirable, a double coil, containing an astatic combination could be placed below the mirror, the upper needle, in that case, serving only as an index. The instrument above described has a coil three inches in diameter and one inch thick; the diameter of the core being one inch. Since its resistance is only about a quarter of an ohm it is intended for use with circuits of small resistance, such as thermo-currents and the like.

The results of a few experiments made with this new vertical-lantern galvanometer will illustrate the working of the instrument, and will demonstrate its delicacy. The apparatus used was not constructed especially for the purpose, but was a part of the University collection.

Induction Currents.—1. The galvanometer was connected with a coil of covered copper wire, No. 11 of the American wire gauge, about ten centimeters long and six in diameter, having a resistance of 0·323 ohm. A small bar magnet, 5 centimeters long and weighing six and a half grams, gave, when introduced into the coil, a deflection of 40°. On withdrawing the magnet the needle moved 40° in the opposite direction.

2. A small coil, 20 centimeters long and 3·5 in diameter, made of No. 16 wire and having a resistance of 0·371 ohm, through which the current of a Grenet battery, exposing 4 square inches of zinc surface, was passing, was introduced into the center of a large wire

coil, whose resistance was 0·295 ohm, connected with the galvanometer. The deflection produced was 20°. The same deflection was observed on making and breaking contact with the battery, the smaller coil remaining within the larger.

3. A coil of No. 14 copper wire, sixty centimeters in diameter, and containing about 40 turns, the resistance of which was 0·85 ohm, was connected with the galvanometer, and placed on the floor. Raising the south side six inches, caused a deflection of 4°. Placing the coil with its plane vertical, a movement of two centimeters to the right or left, caused a deflection of 3°, and of twenty centimeters, of 10°. A rotation of 90° gave a deflection of 12° and one of 180°, of 24°. These deflections were of course due to currents generated by the earth's magnetism.

4. *Thermo-currents.*—Two pieces of No. 22 wire fifteen centimeters long, were taken, the one of copper, and the other of iron wire, and united at one end by silver solder. On connecting the other ends to the galvanometer, the heat of the hand caused a deflection of the needle of 20°.

5. A thermo-pile of 15 pairs, each of bismuth and antimony, was connected to the instrument. The heat from the hand placed at five centimeters distance caused a deflection of 3°.

6. Two cubes of boiling water acted differentially on the pile. At the distance of five centimeters, the deflection was 20°; moving one to ten centimeters, the deflection was reduced to 5°.

7. *Voltaic current.*—A drop of water was placed on a zinc plate. While one of the connecting copper wires touched the zinc, the other was made to touch the water. The deflection was 16°.

The claim which is here made for the instrument however, is rather for the general principle of its construction, than for the advantages possessed by the individual galvanometer above described which was constructed at short notice, to meet an emergency. The comparatively small cost for which it may be fitted to the vertical lantern, the readiness with which it may be brought into use, the brilliantly illuminated circle of light which it gives upon the screen, with its graduated circle and needle, the great range of delicacy which may be given to the instrument by varying the coil and needles, so that all experimental requirements may be answered, and finally, the satisfactory character of its performance as a demonstration galvanometer, all combine to justify the record which is here made of it.

THE RAPID CORROSION OF IRON IN RAILWAY BRIDGES.

By Wm. Kent.

*A Paper presented, by request, to the U. S. Board appointed to examine Iron, Steel, etc.**

It has frequently been noticed that iron used in railway bridges, which is exposed to the smoke, steam and heated gases escaping from the passing locomotives, shows a greater tendency to corrode than iron in situations not so exposed. In some cases the iron beams and rods on the upper part of the bridge have been found to be rusted to such a depth that the safety of the bridge is endangered. It is, therefore, important to learn the causes of this rapid corrosion, in order to know what steps must be taken to prevent it.

A few weeks ago some pieces of iron rust, taken from a bridge on the Pennsylvania Railroad, were sent to the laboratory of the Stevens' Institute by Engineer J. M. Wilson, of the Pennsylvania R. R., and the writer made a qualitative chemical examination of them, to learn whether such examination would reveal any of the causes of the rusting.

The rust was in several pieces, or flat plates, some of which were as much as one-eighth of an inch in thickness. Some were quite friable, being easily broken by the fingers, while others required a light tap with a hammer to break them. All of the plates were covered on the outer side with a thick coating of a sooty nature, which was no doubt finely divided carbon deposited from the smoke of the locomotives. In other respects the rust was in no way distinguishable to the eye from iron rust formed in the atmosphere under ordinary circumstances. A portion of the rust was finely powdered, put into a flask, and distilled water, free from ammonia, added. The flask was tightly corked, and exposed to a gentle heat for two weeks. The water was then filtered off, and examined to find whether anything had gone into solution. It had a strongly bituminous odor, a thin oily film appeared upon the surface, and it was neutral to test paper. A careful qualitative analysis showed the presence, in the water solution, of iron, ammonia, sulphuric acid, and traces of sulphurous

* Sent to this Journal by Prof. Thurston, as a reprint from the *Iron Age*.

acid and chlorine. Nitric and nitrous acids were searched for but could not be found. A separate portion of the rust was tested for carbonic acid, and it was found in considerable quantity. The water solution was evaporated to dryness, and a small grayish residue was left.

The result of the analysis suggests at once the causes of the rapid oxidation of the iron. The presence of carbonic, sulphuric and sulphurous acids, no matter how small in quantity, is sufficient to promote rapid corrosion. The sources from which these substances are derived is evidently the escaping gases of the locomotive, which contain carbonic acid, carbonic oxide, moisture, and if there is sulphur in the coal, sulphurous and sulphuric acids. The chlorine and ammonia found may come either from the atmosphere, or from the water used in the locomotive. It would be interesting to know the action of each of the various gases above mentioned upon iron, to learn which of them has the greatest tendency to cause corrosion. The literature upon the subject is not extensive. One writer, however, Prof. F. Crace Calvert, has conclusively shown that carbonic acid is a most active agent, in presence of moisture, to promote corrosion. I refer to papers describing his experiments, published in the London *Chemical News*, January 28th and March 11th, 1870, and March 3d, 1871, and also to his experiments upon the action of sea water upon iron, published in the *Engineer*, August 25th, 1865, and *Engineering*, December 20th, 1867.

Among other interesting observations Prof. Calvert remarks that Claude Berdoulin first observed in 1683, that ammonia is formed when aërated water acts upon steel. In 1720, E. F. Geoffroy found that iron rust formed in the air contains moisture and ammonia. In his paper of March 3d, 1871, Prof. Calvert states that iron rust is generally supposed to be a hydrated sesquioxide of iron, containing a trace of ammonia, but two analyses made by him show that its constitution is much more complicated.

The following are the two analyses mentioned. The specimens were formed in the atmosphere, where they were carefully protected from any source of of contamination;

	Rust from Conway Bridge.	Llangollen.
Ferric Oxide, ...	93·094	92·900
Ferrous Oxide, ...	5·810	6·177

Carbonate of Iron, ...	0·900	0·617
Silica, ...	0·196	0·121
Ammonia, ...	traces.	traces.
Carbonate of Lime, . . .		0·295

Prof. Calvert asks the question: "Is the oxidation of iron due to the direct action of the oxygen of the atmosphere, or to the decomposition of its aqueous vapor, or does the very small quantity of carbonic acid which it contains determine or intensify the oxidation of metallic iron?" To reply to it, he made a long series of experiments, by exposing perfectly cleaned blades of steel and iron to the action of different gases. After a period of four months, the blades showed the following results:

Dry oxygen—No oxidation.

Damp oxygen—In three experiments one blade only was slightly oxidized.

Dry carbonic acid—No oxidation.

Damp carbonic acid—Slight appearance of a white precipitate upon the iron, found to be carbonate of iron.

Dry carbonic acid and oxygen—No oxidation.

Damp carbonic acid and oxygen—Oxidation very rapid.

Dry and damp oxygen and ammonia—No oxidation.

These facts tend to show that carbonic acid, and not oxygen nor aqueous vapor, is the agent which determines the oxidation of iron in the atmosphere. Prof. Calvert also made experiments upon iron immersed in water containing carbonic acid, in sea water, and in very dilute solutions of hydrochloric, sulphuric and acetic acids. In one case a piece of cast iron placed in a dilute acetic acid solution for two years was reduced in weight from 15·324 grams to 3½ grams, and in specific gravity from 7·858 to 2·731, while the bulk and outward shape remained the same. The iron had gradually been dissolved or extracted from the mass, and in its place remained a carbon compound of less specific weight, and small cohesive force. The original cast iron contained 95 per cent. of iron and 3 per cent. of carbon, the new compound only 80 per cent. of iron and 11 per cent. of carbon. Iron immersed in water containing carbonic acid was also found to oxidize rapidly. Prof. Calvert states that the oxidation in this case was not due to the fixation of the oxygen dissolved in the water, but to oxygen liberated from the water by galvanic action.

The occurrence of hydrogen collected above the liquid in the bottles proved this sufficiently.

When distilled water was deprived of its gases by boiling, and a bright blade introduced, it became in the course of a few days here and there covered with rust. The spots where the oxidation had taken place were found to be impurities in the iron, which had induced a galvanic action, just as a mere trace of zinc placed on one end of the blade would establish a voltaic current.

With these researches of Prof. Calvert before us we have no difficulty in accounting for the rapid oxidation of iron in railway bridges. All the conditions necessary to promote corrosion are present. The carbonic acid and moisture escaping from the locomotives would themselves be sufficient; but when to this we add the sulphuric acid and chlorine, both of which were found in the analysis, we have, when they are dissolved in the moisture, an acid or a saline liquid capable of the most energetic action. Furthermore, the presence of the carbonaceous deposit has no doubt a tendency to assist the corrosion, both by its acting as a nucleus which retains the moisture and acid and condenses the gases within its pores, and by its inducing galvanic action, carbon being electro-negative to iron. The reason of the presence of ammonia in iron rust is stated by Bloxam, who says that it is formed from the nitrogen in the air during the process of rusting. It appears that the water is decomposed by the iron, and the liberated hydrogen enters at once into combination with the nitrogen held in solution by the water to form ammonia.

In connection with this subject, the writer has made an experiment to determine the action of sulphurous acid upon iron, as follows: Two one-half liter flasks were taken, and in one was placed about two ounces of clean and bright wrought iron turnings, and in the other two ounces of old rusty lath nails. Ten cubic centimeters of water was added to each, enough to merely wet the iron, and a current of sulphurous acid gas was then passed into each for a few minutes, and the flasks tightly corked and sealed. The gas had an immediate and energetic action in each case. The bright turnings at once became black, and then a white sandy-like deposit appeared in the bottom of the flask. On shaking this deposit around the side of the flask, it in a few minutes changed to a grayish color, and afterward a part of it became of the color of iron rust. The lath nails in the other flask at first lost their rusty appearance, and then the white deposit ap-

peared as in the first case. A third flask was then taken and ten cubic centimeters of water put in it and filled with sulphurous acid gas and corked, but no iron was put in it. All three flasks were kept corked for a week, and then opened. The third flask had a suffocating odor of sulphurous acid, and the water in the bottom contained both sulphurous and sulphuric acids. The other flasks were entirely free from any smell of sulphurous acid. The water was tested and found to contain protosulphate of iron. The precipitate around the sides of the flask was dissolved in hydrochloric acid and found to contain sulphuric acid and iron, both as ferrous and ferric oxides. The iron nails and turnings were weighed and found to have lost nearly 1 per cent. of their original weight. This experiment seems to show that sulphurous acid is rapidly changed into sulphuric acid in the presence of iron and moisture, and that the iron is thereby rapidly corroded. The sulphurous acid escaping from the locomotives must, therefore, be considered one of the most active agents of the corrosion of railway bridges.

STEVENS' INSTITUTE OF TECHNOLOGY,
Chemical Laboratory, May 19th, 1875.

MOLECULAR CHANGES IN METALS.*

By Prof. R. H. THURSTON.

In a series of articles contributed to the *Scientific American* during the past year, the writer gave an outline of the various phenomena affecting the strength of metals used in construction, and described some that were peculiar in character and but recently discovered, illustrating these facts by graphic representions of the changes of resistance with change of form, such as were obtained by the automatic action of the autographic testing machine of the Mechanical Laboratory of the Stevens' Institute of Technology. There are some phenomena which cannot be conveniently exhibited by strain diagrams;

*Reprinted, with the author's corrections, from the *Scientific American* of March 27th.

such are the molecular changes which occupy long periods of time. These phenomena, which consist in alterations of chemical constitution and molecular changes of structure, are not less important to the mechanic and the engineer than those already described. Requiring, usually, a considerable period of time for their production, they rarely attract attention, and it is only when the metal is finally inspected, after accidental or intentionally produced fracture, that these effects become observable.

The first change to be referred to is that gradual and imperceptible one which, occupying months and years, and under the ordinary influence of the weather, going on slowly but surely, results finally in important modification of the proportions of the chemical elements present, and in a consequent equally considerable change of the mechanical properties of the metal. The process of oxidation, or corrosion, is such a process, and is the most familiar one. Cast and wrought iron are both subject to it, the latter to, by far, the most serious extent. Cast iron is comparatively little affected by oxidation, even where exposed in wet situations or to alternate moisture and dryness. Wrought iron, under ordinary conditions of exposure, is said to be become rusted to the depth of a sixteenth of an inch in a quarter of a century. In exceptionally trying situations, it corrodes far more rapidly. Steam boilers are sometimes rusted through, about the water legs, at the rate of a sixteenth of an inch a year, and instances have been known of even more rapid work than this. Exposure, however, while producing oxidation, has another important effect: It sometimes produces an actual improvement in the character of the metal.

Every mechanic knows that old tools, which have been laid aside or lost for a long time, seem to have acquired exceptional excellence of quality. Razors which have lost their keenness and their temper recover, like mankind, when given time and opportunity to recuperate. A spring regains its tension when allowed to rest. Farmers leave their scythes exposed to the weather, sometimes, from one season to another, and find their quality improved by it. Boiler makers frequently search old boilers carefully, when reopened for repairs after a long period of service, to find any tools that may have been left in them when last repaired; and if any are found, they are almost invariably of unusually fine quality. The writer, when a boy in the shop, frequently if denied the use of their tools by the workmen, looked about the scrap heaps and under the windows for tools purposely or carelessly dropped by the workmen; and when one was found badly

rusted by long exposure, it usually proved to be equal to the best of steel. One of the most striking illustrations of this improvement of the quality of wrought iron with time has recently come to the knowledge of the writer. The first wrought iron T-rails ever made were designed by Robert L. Stevens, about the year 1830, and were soon afterward laid down on the Camden and Amboy Railroad. These were Welsh rails, and, when put down, were considered, and actually were, brittle and poor iron. Many years later, these were replaced by new rails, but until quite recently some still remained on sidings. When a lot of unusually good iron was wanted, some of these rails were taken up and re-rolled into bar iron. The long period of exposure had so greatly changed the character of the metal that the effect was unmistakable. These facts are stated by gentlemen upon whom perfect reliance may be placed.

"But," it will be asked at once, "how can such changes occur without apparent cause, however long the time?" There are probably two methods of improvement, each due to an independent molecular action. In the case of the razor and the spring, which regain their tempers when permitted to rest, it seems probable that a molecular rearrangement of particles, disturbed by change of temperature in one case and by alternate flexing and relaxing in the other, goes on, much as the elevation of the elastic limit and the increase of resisting power, discovered by the writer and shown on the strain diagram, takes place under strain and set. The other cases may probably be due to a combination of this physical change with another purely chemical action, which is illustrated best in the manufacture of steel by the cementation process. In this process, iron, imbedded in charcoal and kept at red heat, gradually absorbs carbon and becomes steel. Here the element carbon enters the solid masses of iron, and diffuses itself with greater or less uniformity throughout their volume. There seems to exist a tendency to uniform distribution which is also seen in a thousand other chemical changes. Many chemical processes are accelerated, checked, and even reversed by simple changes of relative proportions of elements, which compel acceleration or reversal as the only means of securing this uniformity of distribution.

When, therefore, wrought iron containing injurious elements capable of oxidation, is exposed to the weather, the surface may be relieved by the combination of these elements with oxygen, and the surcharged interior, by this tendency to uniform diffusion, is relieved

by the flow of a portion to the surface, there to be oxidized and removed. This process of flow goes on until the metal, after lapse of years perhaps, becomes comparatively pure. Meantime the occurrence of jarring and tremor, such as rails are subjected to, may accelerate both this and the previously described change.

The effect of strains frequently applied, during long intervals of time, is quite different, however, where they are so great as to exceed the elastic range of the material. The effect of stresses which strain the metal beyond the elastic limit has already been referred to in the *Scientific American*. The case of the porter bar (of which a sketch was given, showing how, after a long period of severe usage, it finally broke suddenly, exhibiting the peculiar fracture characteristic of such a method of rupture) will probably be remembered by many readers. A still more marked case has recently come to the notice of the writer.

The great testing machine at the Washington Navy Yard has a capacity of about 300 tons, and has been in use 35 years. Quite recently, Commander Beardslee, whose valuable work has been alluded to in this paper, subjected it to a stress of 288,000 lbs., but it subsequently broke down under about 100 tons. The connecting bar which gave away had a diameter of five inches, and should have originally had a strength of about 1,000,000 lbs. Examining it after rupture, the fractured section was found to exhibit strata of varying thickness, each having a characteristic form of break. Some were quite granular in appearance, but the larger proportion were distinctly crystalline. Some of these crystals are large and well defined. The laminæ, or strata, preserve their characteristic peculiarities, whether of granulation or of crystallization, lying parallel to their axis and extending from the point of original fracture to a section about a foot distant, where the bar was broken a second time (and purposely) under a steam hammer. It thus differs from the granular structure which distinguishes the surfaces of a fracture suddenly produced by a single shock, and which is so generally confounded with real crystallization. This remarkable specimen has been contributed by the Navy Department to the cabinet of the Stevens' Institute of Technology.

The somewhat similar instance of the dropping-off of the end of an immense shaft at the Morgan Iron Works, some time since, while the opposite end was under the steam hammer, has been described in the *Scientific American*.

Were more conclusive evidence required of the occurrence of crystallization of iron, it has recently been given by an interesting incident at the Stevens' Institute of Technology. A student while annealing a number of steel hammer heads, left them exposed all night to the high temperature of the air furnace in the brass foundry. When finishing one of them, a careless blow broke it, and the fractured surface was found to possess a distinctly crystalline character.

[In the illustration, Figure 1 is a magnified representation of the surface of fracture. The two holes shown, penetrating the mass, are those drilled in the first operation, preparatory to fitting the handle. The facets of the crystals are seen to be remarkably perfect and well defined. Figure 2 represents the hammer on very nearly the natural scale.]

Fig. 1.

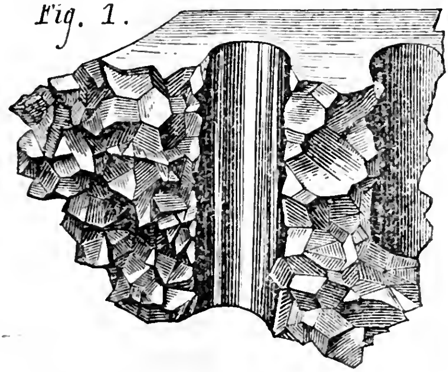
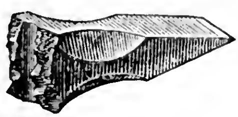


Fig. 2.



In this example, however, the faces were nearly all pentagonal, and were usually very perfectly formed. These illustrations are conclusive of the question whether iron may crystallize under the action of long continued and severe shocks, or of high temperature. When imperfect crystals are developed, it is easy to mistake them, but the formation of pentagonal dodecahedra, in large numbers and in perfectly accurate forms, may be considered unmistakable evidence of the fact that iron may crystallize in the cubic, or a modified, system. This may apparently take place either by very long-continued jarring of the particles beyond their elastic limits, or under the action of

high temperature, by either mechanical or physical tremor. But no evidence is given here that a single suddenly applied force, producing fracture, may cause such a systematic and complete rearrangement of molecules. The granular fracture produced by sudden breaking, and the crystalline structure produced as above during long periods of time, are, apparently, as distinct in nature as they are in their causes. The broken hammer head is so beautiful and perfect an illustration, and such instances are so rare, that it has been drawn and engraved by the accomplished gentlemen attached to the *Scientific American*, and is given in this article as the first illustration of the kind which has appeared in the literature of engineering.

STEVENS' INSTITUTE OF TECHNOLOGY, *Hoboken, N.J.*

On the Manufacture of Paper.—M. Aimé Girard, Professor at the Conservatoire des Arts et Metiers of Paris, has recently communicated to the French Academy, the results of his micrographic study of the tissues employed in paper making, which will be of interest to those engaged in this branch of manufacture. M. Girard has determined under the microscope the form, the dimensions and the special characteristics of each of the fibers employed in paper making at the present day. He has also made photo-micrographs of these fibers. As a result of these examinations, he has been led to formulate the precise conditions which a fiber of good quality for making paper, should fulfill.

Very much has been said, for example, of the value of length in fibers designed for use in the manufacture of paper; but this concern about long fiber has no foundation in the facts of the case. The crude, and in fact the finished pulp, is composed of fragments measuring either from 0·3 to 0·5 of a millimeter, in short pulp; or from one to one and a half millimeters, (one twenty-fifth to one sixteenth of an inch) in the long pulp; it is rare to find this length exceeded. Now there is no vegetable fiber known, the length of which is not at least equal to the latter figures. Hence there is no vegetable fiber too short for the manufacture of paper.

There is however a condition which is of extreme importance in this relation. It is that the fiber should be fine and elongated; that, in a word, the ratio of its length to its diameter should be considerable. This ratio, for a fiber, after cutting and pulping in the paper machine, should be as 50 to 1 as a minimum; moreover, the fiber

should be elastic; and finally, it should be flexible and capable of being bent and twisted with facility. It is under these conditions alone that the felting of the fiber can give solidity to the sheet. On the contrary, the tenacity of the fiber, which is sometimes considered so essential, has in fact only a secondary importance; since when a sheet of paper is torn, the fibers themselves are almost never ruptured, but escape entire from the felted mass by sliding over their neighbors. In short, the value of a vegetable fiber designed for the manufacture of paper does not depend, as is so often asserted, upon its length, nor even upon its tenacity, but before all these, upon its elasticity, upon the fineness of its diameter, and upon the facility with which it may be bent on itself.

Having fixed these principles, M. Girard classifies provisionally, while awaiting the results of further research, the principle substances employed in the manufacture of paper into five different groups. These classes comprise: 1st, Round fibers having well marked nodes. 2d, Smooth fibers or fibers with indistinct nodes. 3d, Fibro-cellular substances. 4th, Flat fibers; and 5th, Imperfect materials.

1. *Round fibers with well defined nodes.*—Such fibers are those of hemp and flax. The textile fiber of hemp is different from its paper-making fiber. The former is composed of finer fibers cemented together, and forming large bundles even one-tenth of a millimeter in diameter. In the pulp of hemp scrap, the fibers are detached from the bundles and are separately visible, appearing in the form of nearly cylindrical rods, intersected by frequent transverse nodes which give to them the appearance of bamboos. The diameter of these fibers varies from one-fiftieth to one-eightieth of a millimeter. These fibers are fissile, splitting easily into a multitude of fibrillæ, which clasping each other firmly, give to the paper made from canvas, a very great solidity. Flax presents in its fibers, great similarity with hemp. But its fissility is less pronounced and the diameter of the fibrillæ is less, varying from one-eightieth to one-hundreth of a millimeter.

2. *Round smooth fibers, nodes indistinct.*—In this class belong esparto grass, jute, phormium fiber, palmetto, hop, and sugar cane. England consumes annually 250,000 tons of esparto grass. Its fiber is fine and slender, measuring only one-hundredth of a millimeter in diameter, and being five millimeters in length. These fibers felt together very well. Of jute, England consumes 200,000 tons a year. Under this name are included various East Indian vegetable products. The fibers, while closely analogous for the different varieties, resemble

in general those of hemp and flax. The fibers of *phormium tenax* are very similar to those of esparto, and felt well together. The palmetto, when treated chemically, gives round fibers, having nodes, but much finer than those of hemp or flax. The hop has recently begun to attract the serious attention of manufacturers, and for some time, it has been employed for paper making. An important advance has lately been made in this direction, by improvements made in the construction of machines for decorticating the plant. From the bark thus detached, two sorts of fibers, mixed together, are extracted. One of these, and this the most abundant, measures about one-hundreth of a millimeter; the other measures about one-thirtieth of a millimeter. The latter seem to possess a certain fissility, analogous to flax and hemp. Sugar cane is at present treated in the Antilles by a chemical process. From the bagasse, fibers are extracted in this way, which are round and regular, and which may be readily bent and twisted.

3. *Fibro-cellular substances.*—Of these the most common, is the pulp obtained from rye or wheat-straw, by submitting it to the action of caustic soda under pressure, at a temperature of 120° to 130° C. This pulp is a mixture of round fibers with indistinct nodes, which bend easily, with larger grains or cellules of various forms. It is to the presence of these grains, incapable of being felted or bent, that M. Girard attributes the defects recognized in all straw paper.

4. *Flat fibers.*—These fibers comprise those of cotton, of wood extracted by chemical processes, of the agave, of the paper mulberry and of the bamboo. The flat fibers of cotton are easily bent. The polygonal fibers of pine and fir wood, split up into flat fibers, in the middle of which the dotted tissue appears. The production of these fibers is to-day a very wide spread mechanical industry. The fiber of the agave is flat and easily twisted. The mulberry gives a flat and very long fiber. The trial of the bamboo for the benefit of the paper maker seems on the eve of assuming a considerable industrial importance. The fiber, analogous to that of the paper mulberry, is flat and may be bent with facility.

5. *Imperfect materials.*—In concluding this list of the vegetable substances employed in the manufacture of paper, it is necessary to mention the pulp obtained by the mechanical comminution of wood. This pulp is not made up of fibrous materials, properly so-called. It is composed of bundles of fibers, still adhering together, sometimes in so great a number as to constitute true sticks. The element thus mechanically produced from the wood is a rigid fragment, incapable of being bent, or of giving a solid felt. The introduction of such material into paper can produce only very unsatisfactory results.